Ministry
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Ontario

Water Resources
Report 9a

Geology and Water Resources of the Bowmanville, Soper and Wilmot Creeks IHD Representative Drainage Basin

INTERNATIONAL HYDROLOGICAL DECADE · DÉCENNIE HYDROLOGIQUE INTERNATIONALE

To George.

May you learn something about hydrogeology from this.

Gunther

Ontario

WATER RESOURCES
REPORT 9a

Geology and Water Resources of the Bowmanville, Soper and Wilmot Creeks IHD Representative Drainage Basin

By
Gunther Funk

MINISTRY OF THE ENVIRONMENT
Water Resources Branch

Toronto Ontario

1977

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PREFACE

The Bowmanville, Soper and Wilmot creeks basin was one of the five representative drainage basins in southern Ontario studied as part of the Ministry's contribution to the International Hydrological Decade program (IHD). This program was initiated in 1965 to study basins which are representative of larger physiographic areas. The "Geology and Ground Water Resources of the Bowmanville, Soper and Wilmot Creeks IHD Representative Drainage Basin" is the third in a series of several reports on this program.

G.H. Mills, Director
Water Resources Branch

Toronto, November, 1977

ENGLISH - METRIC (SI) FACTORS

to convert	to	multiply by
inches (in)	centimetres (cm)	2.540
feet (ft)	metres (m)	0.305
miles (mi)	kilometres (km)	1.609
square miles (mi^2)	square kilometres (km^2)	2.590
cubic feet/second (cfs)	litres/second (l/s)	28.316
Imperial gallons (Ig)	litres (l)	4.546
Imperial gallons/day (Igpd)	litres/second (l/s)	5.262×10^{-5}
Imperial gallons/day/ft^2 ($Igpd/ft^2$)	metres/second (m/s)	5.663×10^{-7}
Imperial gallons/day/ft (Igpd/ft)	square metres/second (m^2/s)	1.726×10^{-7}
Imperial gallons/min (Igpm)	litres/sec (l/s)	.0758

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ABSTRACT

This report describes the geology and ground-water resources of the Bowmanville, Soper and Wilmot creeks drainage basin. This basin is representative of a number of drainage basins in south-central Ontario characterized by a moraine (Oak Ridges Moraine) in the northern portion of the basins, a drumlinized till plain (South Slope) in the centre and a lacustrine clay plain (Lake Iroquois Plain) in the south.

The bedrock units underlying the thick overburden deposits consist of the Lindsay Formation of Middle Ordovician age, an argillaceous limestone, and the Whitby Formation of Upper Ordovician age, a calcareous black shale. The overburden consists of glaciolacustrine, glaciofluvial and glacial sediments of Pleistocene age and alluvium, aeolian, beach, muck and swamp deposits of Recent age.

The thick glaciofluvial deposits constitute the major aquifers. Thicknesses of up to 325 feet of sand and gravel have been measured in the observation wells finished in the Oak Ridges Moraine. The saturated portion of the sand and gravel measures almost 170 feet. Numerous sand and gravel lenses and beds are encountered in the wells finished in the South Slope and Lake Iroquois Plain. Some of deposits are southward extensions of those of the Oak Ridges Moraine, the majority are discontinuous glaciolaustrine and glaciofluvial sediments deposited prior to the formation of the moraine.

Ground and surface waters are used extensively for irrigation, stock watering and for water-supply purposes. Favourable hydrogeologic conditions have resulted in a high rate of success in the drilling of wells and in the obtaining of satisfactory supplies of water. Inadequate supplies are probably a result of construction difficulties (fine sand or insufficient depth) rather than a lack of water.

The chemical quality of the ground waters, although varying with sample location and depth, is for the most part excellent. The waters are typically of the calcium-bicarbonate type. There is some increase in the total mineralization of the ground water from north to south in the basin. The chemical quality of the surface and seepage waters is similarily good and also shows an increase in mineralization from north to south.

Figure 1. Location of the Bowmanville, Soper and Wilmot Creeks drainage basin in southern Ontario.

INTRODUCTION

PRESENT STUDY

This study, one of a series conducted on representative drainage basins in southern Ontario as part of the Ministry's contribution to the International Hydrological Decade (IHD) program, is a preliminary investigation of the ground-water resources in the Bowmanville, Soper and Wilmot (BSW) creeks drainage basin. The fundamental objectives of this study are:

1. to determine the physical characteristics of the major geologic units in the basin,
2. to assess the water-bearing properties of these different geologic units,
3. to determine the occurrence, availability and quality of the ground water, and
4. to approximate the ground-water flow pattern.

The initial phase of this investigation consisted of examining water-well records on file at the Ministry of the Environment (MOE) office in Toronto, in order to establish site locations for the installation of observation wells where geologic and hydrologic controls were limited. This was followed by field work, including an inventory of existing wells, establishing observation wells, conducting short-term pumping tests on these observation wells and collecting water samples.

Geological control was provided by reference to existing publications, water-well records, detailed logs kept for the observation wells and surficial mapping conducted in 1966-1967 and 1974.

PREVIOUS INVESTIGATIONS

The Paleozoic rocks both underlying and adjacent to the study area have been described by Caley (1940), Liberty (1953, 1955, 1964 and 1969), and Hewitt (1972). Other information on the Paleozoic rocks, such as their lithology, is contained in water-well records maintained by the Ministry of the Environment.

Previous investigations on Pleistocene geology include the early work of Wilson (1905), who described the exposures of three till sheets in a high shorecliff near Newcastle, and Coleman (1904, 1909, 1932 and 1936) who delineated the old Lake Iroquois shoreline. In addition, physiographic and surficial geologic mapping was carried out by Gravenor (1957) and by Chapman and Putnam (1966). The overburden geology of the shorebluffs area near Bowmanville was re-examined by Singer (1973, 1974).

A detailed soils map of Durham County, prepared for the Ontario Soil Survey by Webber, Morvick and Richards (1946), contributed to the knowledge of the area.

Various aspects of the ground-water resources in the BSW basin have been examined by Barouch (1971, a and b) and Singer (1974). Barouch, using the physical parametric approach, evaluated the ground-water storage capacity of the Soper Creek sub-basin in one report, while in another, he dealt with hydrograph separation in the Wilmot Creek sub-basin applying both recession factor analysis and streamflow chemistry. The ground-water potential for the area south of the abandoned Lake Iroquois shoreline has been examined in detail by Singer. Singer's hydrogeological evaluation for that portion of the study area has been

briefly summarized in this report. In addition, the MOE has conducted several field surveys in the area including a land-use survey (data unpublished) as part of the overall IHD representative basin study.

ACKNOWLEDGEMENTS

Sincere appreciation is expressed to all staff of the former River Basin Research Section for their field and office assistance. M. Barouch was involved with the initial aspects of this study through data collection, geological mapping, and interpretation.

Special thanks are due to S. Singer, J. Coward and U. Sibul for their numerous discussions with the author as to the presentation and interpretation of the data. A. Babaris is also to be thanked for his contribution to the technical aspects of the study and Ms. V.E. Sokolyk and Ms. R. Smith for time spent typing this manuscript.

All mechanical and carbonate analyses were undertaken by D. Donohue. Appreciation is also expressed to the residents of the area who kindly permitted their wells to be measured and sampled.

GEOGRAPHY

LOCATION

The Bowmanville, Soper and Wilmot creeks drainage basin is located in Southern Ontario, on the north shore of Lake Ontario, in the Regional Municipality of Durham, formerly the united counties of Northumberland and Durham.

It is covered by sheets 30 M/15 East and 31 D/2 East of the National Topographic Series, within the co-ordinates latitude 78°30'W to latitude 78°53'W. The location of the basin is shown on Figure 1.

The area of the basin is 104.1 square miles and is subdivided into three major sub-basins: the Bowmanville, Soper and Wilmot creeks.

PHYSIOGRAPHY

The regional physiographic features have been described by Gravenor (1957) and Chapman and Putnam (1966).

The Bowmanville, Soper and Wilmot creeks drainage basin incorporates three major physiographic divisions, the Oak Ridges Moraine, the South Slope and the Lake Iroquois Plain (Lake Plain). Each physiographic division has distinctive slope, soil type and runoff characteristics. In this report, the physiographic divisions are represented by land forms or land-form assemblages as follows:

Major Physiographic Division	Land Form
Oak Ridges Moraine	upland
South Slope	rolling till plain
Lake Iroquois Plain	a. upper lake plain-irregular
	b. lower lake plain-flat

The areal distribution of these physiographic subdivisions is illustrated in Map 1.

The Oak Ridges Moraine stands as one of the most distinctive physiographic units. Forming the height of the land in the northern section of the basin, it divides the drainage south into Lake Ontario and north into Lake Scugog. The elevation of the upland area ranges from approximately 900 feet to 1,200 feet above mean sea level, the major drop in elevation being along its southern boundary. The average slope to the south is about 120 feet per mile.

South of the Oak Ridges Moraine is the South Slope which is a rolling till plain. The elevation of the till plain ranges from about 500 feet to about 1150 feet above mean sea level (asl). The region has an average slope of about 75 feet per mile.

The upper lake plain of the Lake Iroquois Plain has an irregular low relief surface and includes the Iroquois shore and nearshore deposits. The northern limit follows the abandoned Lake Iroquois shoreline and is marked by bar and beach deposits. Elevations along this northern limit range from 508 feet at the western end of the study area increasing gradually to 532 feet at the eastern end. This variation in elevation is a function of isostatic readjustment following recession of the last glacial advance. The southern boundary of the plain, a gradational boundary between coarse and fine-grained offshore deposits, is at about 400 feet (asl). The upper lake plain has an average slope towards the south of about 60 feet per mile.

The lower lake plain is an area of very low relief, which has been smoothed by wave action in the former Lake Iroquois. Some drumlins (drumlinoids), having stood as islands in the old lake, interrupt the continuity of the flat plain. The elevation of the lower lake plain ranges from about 250 feet to about 400 feet (asl). The plain has an average slope towards the south of about 50 feet per mile.

DRAINAGE

The basin is drained by three main creeks: the Bowmanville, Soper and Wilmot creeks.

The Bowmanville Creek drains an area of 33.39 square miles. The main branch rises in the Oak Ridges Moraine about one and a half miles west of Burketon Station, at an elevation of about 1000 feet and flows southeast for a distance of about 13.59 miles to its outlet into Lake Ontario at Port Darlington. It has a total fall of about 650 feet with an average slope of 0.0102 feet per foot.

The Soper Creek drains an area of 29.86 square miles. The main branch rises north of Tyrone, at an elevation of about 990 feet and flows southerly to its confluence with the Bowmanville Creek in a marshy bay, about one and a half miles upstream from Lake Ontario. The Soper Creek has an overall length of about 13.24 miles, a total fall of about 745 feet and an average slope of about 0.0117 feet per foot.

The Wilmot Creek drains an area of about 31.89 square miles. The main branch rises four miles north of Leskard, at an elevation of about 1,060 feet and flows south for a distance of about 9.64 miles to its outlet into Lake Ontario. It has a total fall of about 740 feet with an average slope of about 0.0045 feet per foot.

CLIMATE

The presence of Lake Ontario to the south gives this region an overall temperate climate. Both temperature and precipitation are relatively constant from year to year as indicated by the data presented in tables 1 and 2.

The mean annual precipitation (1967-1973) averaged for the nine recording stations in the basin is 33.13 inches. Over this period, the annual precipitation ranged from 30.70 inches for the "driest" year to 38.26 inches for the "wettest" year. Table 1 presents the monthly averages per year and the average for the interval from 1967 to 1973.

Temperature data for three stations are presented in tables 2a. b.& c. The mean annual temperature at the Bowmanville-Mostert station for the period 1968 to 1973 is 44.4^{o}F, with a mean maximum temperature of 52.5^{o}F and a mean minimum temperature of 32.6^{o}F. The mean annual temperature at the Orono station for the same interval is 43.7^{o}F, with a mean maximum and minimum of 53.0 and 34.3^{o}F, respectively. The mean annual temperature at the McLaughlin station for the interval 1969 to 1974 is 43.0^{o}F with a mean maximum temperature of 50.1^{o}F and a mean minimum temperature of 36.0^{o}F. The monthly precipitation and temperature data are presented in Appendix A.

TABLE 1. PRECIPITATION ANALYSIS

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Avg.	Total/Year
1967	2.93	1.79	1.18	3.45	2.78	5.24	4.13	2.12	3.42	3.63	3.36	2.76	3.07	36.84
1968	2.72	1.82	2.35	1.06	4.01	2.56	0.73	3.33	2.86	2.19	4.48	3.09	2.60	31.20
1969	2.42	0.65	1.41	3.42	3.44	2.47	4.50	3.40	0.46	2.54	3.88	2.25	2.56	30.70
1970	2.12	1.71	2.55	2.84	2.43	2.17	3.32	1.43	2.45	4.35	2.57	3.07	2.58	30.96
1971	2.16	3.47	1.74	1.11	1.21	4.69	3.08	2.93	2.16	2.16	2.42	3.91	2.59	31.08
1972	1.88	3.17	3.31	2.80	2.05	3.36	3.25	4.57	2.55	3.37	2.71	4.70	3.18	38.16
1973	1.67	1.57	4.30	3.15	4.00	2.56	1.46	2.20	1.76	4.06	3.59	2.67	2.75	33.00
Avg.	2.27	2.03	2.41	2.55	2.85	3.29	2.92	2.85	2.24	3.15	3.29	3.21	2.76	33.13

Average monthly precipitation from 1967 to 1973 - 2.76 inches
Mean annual precipitation - 33.13 inches

Stations where precipitation values were taken (averaged in all stations):
Bowmanville-Mostert, McLaughlin, Orono, Tyrone, Leskard, Hampton, Happy Valley, Clarke, Bowmanville-STP.

TABLE 2a. TEMPERATURE ANALYSIS (BOWMANVILLE-MOSTERT STATION)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Avg.
1968													
Mean Max	23.6	25.4	40.4	54.8	58.8	69.8	74.7	75.3	70.8	58.9	43.0	30.1	52.1
Mean Min	8.5	9.8	23.2	33.7	41.1	50.8	54.8	54.5	51.7	40.0	29.9	16.7	34.6
Mean	16.1	17.6	31.8	44.3	50.0	60.3	64.8	64.9	61.3	49.5	36.5	23.4	43.4
1969													
Mean Max	28.2	32.0	36.3	53.7	60.3	-	76.7	77.8	69.0	55.4	44.4	28.3	51.1
Mean Min	14.7	18.1	21.3	33.5	41.0	-	56.6	56.1	47.9	37.8	32.9	15.0	34.1
Mean	21.5	25.1	28.8	43.6	50.3	-	66.7	52.0	58.5	46.6	38.7	21.7	42.6
1970													
Mean Max	21.3	28.6	35.9	53.1	61.4	72.9	76.6	77.6	68.9	58.3	46.5	28.6	52.4
Mean Min	2.5	12.4	21.1	33.1	42.3	49.9	58.1	54.6	49.4	42.7	47.5	14.2	35.6
Mean	11.9	20.5	28.5	43.1	51.9	61.4	67.4	66.1	59.2	50.5	47.0	21.4	43.99
1971													
Mean Max	24.4	30.4	33.7	49.4	63.0	71.8	77.6	74.7	71.2	62.9	43.4	36.5	53.3
Mean Min	6.9	16.3	19.3	31.7	40.7	50.8	53.9	52.1	52.6	43.6	29.6	21.2	34.9
Mean	15.7	23.4	26.5	40.6	51.9	61.3	65.8	63.4	61.9	53.3	36.5	28.9	44.1
1972													
Mean Max	31.2	27.6	33.1	45.9	64.7	69.0	76.1	72.7	68.9	51.6	40.6	33.0	51.2
Mean Min	13.0	9.4	17.6	29.1	42.8	50.1	55.7	54.5	49.9	35.2	30.1	19.8	41.1
Mean	22.1	18.5	25.4	37.5	53.8	59.6	65.9	63.6	59.4	43.2	35.4	26.4	46.1
1973													
Mean Max	31.3	28.4	46.3	51.6	59.7	74.2	79.1	80.2	70.8	59.5	44.8	31.9	54.8
Mean Min	16.9	10.8	30.9	35.0	42.8	54.0	57.2	59.0	46.7	40.7	32.2	18.3	37.0
Mean	24.1	19.6	38.6	43.3	51.3	64.1	68.2	69.6	58.8	50.1	38.5	25.1	45.9
Monthly Average (1968-73)													
Mean Max	26.7	28.7	37.6	51.4	61.3	71.5	76.8	76.4	69.9	57.8	43.8	31.4	52.5
Mean Min	10.4	12.8	22.2	32.7	41.8	51.1	56.1	55.1	49.7	40.0	33.7	17.5	36.2
Mean	18.6	20.8	29.9	42.1	51.6	61.3	66.4	65.8	59.8	48.9	38.8	24.5	44.4

TABLE. 2b. TEMPERATURE ANALYSIS (ORONO STATION)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Avg.
1967													
Mean Max	-	25.4	36.0	51.2	57.3	77.1	76.1	75.5	70.0	56.0	39.6	34.8	54.5
Mean Min	-	7.1	20.2	29.9	34.1	56.3	56.9	55.9	47.9	40.0	27.7	22.3	36.2
Mean	-	16.3	28.1	40.6	46.1	66.7	66.5	65.7	59.0	48.0	36.7	28.6	45.4
1968													
Mean Max	24.1	25.9	41.5	56.3	60.7	73.0	80.0	77.6	72.1	59.1	42.1	28.5	53.4
Mean Min	7.8	8.8	22.9	35.0	42.8	51.8	56.0	55.0	52.6	40.8	29.7	15.6	34.9
Mean	16.0	17.4	32.2	45.7	51.8	62.4	68.0	66.3	62.4	49.9	35.9	22.1	44.2
1969													
Mean Max	27.9	31.1	35.4	54.5	63.1	70.7	78.7	79.9	69.7	55.6	44.2	27.5	53.2
Mean Min	13.0	16.7	19.5	34.1	42.0	50.6	57.4	57.2	48.7	38.0	32.1	14.5	35.3
Mean	20.5	23.9	27.4	44.3	52.2	60.7	67.8	69.0	59.2	46.8	38.2	21.0	44.3
1970													
Mean Max	21.0	27.8	35.0	55.0	64.0	74.3	78.6	79.1	-	-	45.2	27.8	50.8
Mean Min	3.8	8.5	19.3	33.5	42.7	49.5	58.2	56.6	-	-	32.2	12.6	31.7
Mean	12.4	18.2	27.2	43.3	53.4	61.9	68.4	67.4	-	-	38.7	20.2	41.2
1971													
Mean Max	23.7	30.0	33.0	48.6	64.1	74.1	76.7	75.8	71.3	63.6	41.6	35.0	53.1
Mean Min	7.3	13.8	17.7	29.7	38.9	49.4	53.7	51.8	51.4	44.2	25.0	20.3	33.6
Mean	15.5	22.6	25.4	39.2	51.5	61.8	65.2	63.8	61.4	53.9	33.3	27.7	43.4
1972													
Mean Max	30.1	27.0	32.7	46.4	67.2	70.4	78.3	74.3	69.4	51.4	39.0	31.9	51.5
Mean Min	10.7	7.5	16.6	27.6	42.0	48.7	55.0	54.1	49.3	32.6	27.0	17.5	32.4
Mean	20.4	17.3	24.7	37.0	54.6	59.6	66.7	64.2	59.4	42.0	33.0	24.7	41.9
1973													
Mean Max	29.6	27.7	45.6	51.8	60.3	75.2	80.1	81.7	70.4	59.8	43.9	29.7	54.7
Mean Min	14.3	8.0	29.8	33.2	41.8	53.4	57.6	59.4	47.3	39.7	30.4	16.9	36.0
Mean	22.2	17.9	37.7	42.5	51.1	64.3	68.9	70.6	58.9	49.8	37.2	23.3	45.4
Monthly Average (1967-73)													
Mean Max	26.1	27.8	37.0	44.6	62.4	73.5	79.3	77.7	70.5	57.6	42.2	30.7	53.0
Mean Min	9.6	10.1	20.9	31.9	40.6	51.4	56.4	55.7	49.5	39.2	29.2	17.1	34.3
Mean	17.8	18.9	28.9	38.2	51.5	62.4	67.9	66.7	60.0	48.4	35.7	23.9	43.7

TABLE 2c. TEMPERATURE ANALYSIS (McLAUGHLIN STATION)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Avg.
1969													
Mean Max	34.1	27.1	31.2	51.5	60.5	67.4	75.6	77.2	68.2	53.4	40.4	-	55.3
Mean Min	9.7	14.3	18.3	33.7	42.6	51.6	58.0	59.0	50.7	38.7	30.8	-	37.0
Mean	21.5	20.7	24.8	42.6	51.6	59.5	66.8	68.1	59.45	46.0	35.6	-	46.2
1970													
Mean Max	17.9	24.4	31.2	51.2	61.9	71.5	75.9	75.4	66.3	56.3	42.5	24.8	49.9
Mean Min	4.3	8.8	18.3	33.8	44.4	51.8	59.3	57.5	51.1	43.2	32.8	13.2	34.9
Mean	11.1	16.6	24.8	42.5	53.2	61.6	67.6	66.4	58.7	49.8	37.6	19.0	42.4
1971													
Mean Max	20.0	26.6	29.7	45.4	61.6	72.7	73.0	73.3	68.9	61.3	39.9	32.9	50.4
Mean Min	5.2	14.0	17.8	29.5	42.5	53.9	56.4	55.3	54.2	46.6	27.9	19.3	35.2
Mean	12.6	20.3	23.8	37.4	52.0	63.3	64.7	64.3	61.6	54.0	33.9	26.1	42.8
1972													
Mean Max	27.1	23.2	28.7	42.6	64.5	67.7	75.5	71.8	66.2	48.8	36.8	29.7	48.6
Mean Min	10.5	8.3	14.9	27.3	46.7	51.0	58.4	55.8	50.9	34.7	27.7	17.1	33.6
Mean	18.8	15.8	21.8	35.0	55.6	59 4	67.0	63.8	58.6	41.8	32.2	23.4	41.1
1973													
Mean Max	26.8	24.2	42.6	49.3	58.1	72.0	77.4	78.5	68.1	57.4	40.3	27.8	51.9
Mean Min	14.5	8.3	29.8	33.8	42.6	55.9	59.4	61.2	50.1	43.5	29.8	16.0	37.1
Mean	20.6	16.2	36.2	41.6	50.4	63.9	68.4	69.8	59.1	50.4	35.0	21.9	44.5
1974													
Mean Max	25.4	21.9	33.0	34.6	57.4	69.6	75.8	74.8	63.7	53.6	39.9	31.5	48.4
Mean Min	13.6	7.8	19.6	52.7	41.0	52.3	58.4	57.8	46.9	33.8	30.0	23.4	36.4
Mean	19.5	14.8	26.3	43.6	49.2	61.0	67.1	66.3	55.3	43.7	35.0	27.4	42.4
Monthly Average (1969-74)													
Mean Max	25.2	24.6	32.7	45.8	60.7	70.2	75.5	75.2	66.9	55.1	40.0	29.3	50.1
Mean Min	9.6	10.2	26.4	35.1	43.3	52.8	58.3	57.8	50.7	40.1	29.8	17.8	36.0
Mean	17.4	17.4	34.3	40.4	52.0	61.5	66.9	66.5	58.8	47.6	34.9	23.6	43.0

BASIN INSTRUMENTATION

A number of meteorological and hydrological stations have been established in the Bowmanville, Soper and Wilmot creeks basin in order to supply data for the representative basin studies. Map 2 shows the site locations and instrument numbers for these stations. Table 3 presents the purpose, length of record and status of the data for each station. The location and identification numbers for the observation wells are also included on Map 2.

TABLE 3. HYDROLOGIC DATA - BOWMANVILLE, SOPER AND WILMOT CREEKS BASIN

Instrument Number	Purpose	Length	Status of Data
W1	Streamflow	from April 1967	Mean daily flows available to date
	Conductivity	from February 1971	Average daily conductivity available to December 1972
	Water Quality	June 1967-May 1969	Raw (unprocessed) data, chemical analyses available for above period
W2	Streamflow	from October 1965	Mean daily flows
W3	Streamflow	from October 1967	Mean daily flows
W4	Streamflow	from November 1969	Mean daily flows
W5	Streamflow	from November 1969	Mean daily flows
S1	Streamflow	from November 1967	Mean daily flows
	Water Quality	July 1967-May 1969	Raw data
S2	Streamflow	from October 1966	Mean daily flows
S3	Streamflow	from November 1965	Mean daily flows
S4	Streamflow	from November 1965	Mean daily flows
B1	Streamflow	from March 1967	Mean daily flows
	Water Quality	July 1967-May 1969	Raw data
B2	Streamflow	from November 1965	Mean daily flows
	Water Quality	June 1967-May 1969	Raw data
B3	Streamflow	from March 1966	Mean daily flows
B4	Streamflow	from July 1966	Mean daily flows
McLauglin Main Climate Station	Meteorology	from May 1967	Summaries are available to date
Orono Climate Station	Meteorology	from January 1940	Summaries are available to date
Bowmanville-Mostert Climate Station	Meteorology	from November 1967	Summaries are available to date
Satellite Climates (4)	Precipitation & temperature	from January 1966	Summaries are available to date
Sacramento Gauges (3)	Storage Precipitation	from January 1966	Summarized to November 1972
Soil Moisture Sites (4)	Soil Moisture	from August 1968	Soil moisture by volume calculated to the end of 1972
Snow Courses (3)	Snow Precip.	from December 1966	Snow course data available to date
B1	Ground Water	from Aug. 1966	Hydrographs from August 1966
B2	Ground Water	from Sept. 1966	Hydrographs from September 66 to February 1971, monthly readings from May 1971
S1(b)	Ground Water	from Aug. 1966	Hydrographs from December 1965
S1(a)	Ground Water	from Aug. 1966	Hydrographs from August 1966
W8	Ground Water	from April 1968	Monthly readings plotted from April 1968
W9	Ground Water	from May 1968	Hydrographs from May 1968
W10	Ground Water	from May 1968	Monthly readings from May 1968
B4	Ground Water	from Sept. 1966	Monthly readings from September 1966
S4	Ground Water	from August 1966	Monthly readings from August 1966
S5	Ground Water	from August 1966	Monthly readings from August 1966
S6a	Ground Water	from August 1966	Hydrographs from August 1966
S6b	Ground Water	from August 1966	Monthly readings from August 1966
S7	Ground Water	from August 1966	Hydrographs from August 1966
W1	Ground Water	from August 1966	Hydrographs from August 1966
W2	Ground Water	from June 1966	Hydrographs from June 1966
W3	Ground Water	from August 1966	Hydrographs from August 1966
W5a	Ground Water	from August 1966	Monthly readings from August 1966
W5b	Ground Water	from August 1966	Monthly readings from August 1966
W7	Ground Water	from August 1966	Monthly readings from August 1966

GEOLOGY

The significant bedrock formations and the surficial geology of the Bowmanville, Soper and Wilmot creeks basin are discussed in the following sections.

BEDROCK GEOLOGY AND TOPOGRAPHY

Although the bedrock units are not exposed in the study area, their position and lithology can be interpreted from water-well records and bedrock exposures outside the basin. These bedrock exposures occur to the west of the basin along the Rouge River and Little Rouge Creek intermittently for a distance of one and one-quarter miles. Another exposure is in the St. Mary's Cement Company quarry near the Town of Bowmanville. At this location, a 150-foot section of bedrock is exposed below 25 feet of Pleistocene deposits. The subsurface bedrock geology as interpreted by Hewitt (1972) is presented in Map 3.

Liberty (1969) classified the outcropping rocks along the Rouge River as the Whitby Formation of Upper Ordovician age. Both the Whitby Formation and the older Lindsay Formation can be viewed in the St. Mary's Cement quarry.

The oldest rocks underlying the overburden in the basin are those of the Lindsay Formation of Middle Ordovician age (Map 3). The Lindsay Formation as described by Liberty (1969) is a grey to greenish-grey, fine-grained argillaceous limestone in beds from one inch to two feet thick. Shale partings as well as lenses of calcarenite, conglomerate and breccia are abundant. This formation is locally fossiliferous and is defined as containing "Rafinesquina deltoidea beds", and "Hormotoma and Fusispira beds" (Liberty, 1969). The contact with the younger Whitby Formation is reported to be an unconformity.

The Whitby Formation, introduced by Liberty (1955) as a group term, was later redefined to formation rank (Liberty 1969). This formation is divided into three members, the Lower, Middle and Upper, of which the Lower and Middle members outcrop in the vicinity of the basin. The Lower Member consists of highly petroliferous and calcareous black shales with some limestone beds. This member is fossiliferous and pyrite crystals are common. The Middle Member was formerly named as the Rouge River Formation (Liberty, 1955). This member is approximately 90 feet thick in the Toronto area and is described as a brownish, slightly petroliferous soft shale (Liberty, 1969).

Elevation contours of the bedrock surface have been approximated using data from water-well records. Although sufficient data are available for contouring the southern portion of the basin (Singer, 1974), the control data above the 350-foot bedrock contour is sparse and the bedrock topography requires considerable interpretation. To aid in contouring the northern region, it is assumed that the contours are roughly parallel to those in the southern region. Singer (1974) found similarities between the present surface topography and that of the bedrock topography.

The bedrock surface in the Bowmanville, Soper and Wilmot creeks basin has a maximum estimated relief of approximately 300 feet, as shown on Map 3. The bedrock elevation along the Lake Ontario shoreline is approximately 225 feet (asl), while that in the northern portion of the basin exceeds 500 feet. The maximum local relief is generally in the order of 30-70 feet.

TABLE 4. THE GENERALIZED STRATIGRAPHIC COLUMN AS TENTATIVELY PROPOSED FOR THE BOWMANVILLE, SOPER AND WILMOT CREEKS BASIN

System	Formation or Group	Lithology
Recent	Lake Ontario beaches, alluvial deposits and aeolian deposits	gravel, sand, silt, clay, muck, and peat
Pleistocene	Lake Iroquois Deposits	gravel, sand, silt, clay
	Upper Drift Unit	sandy to silty till, with ice contact silt, sand and gravel
	Middle Drift Upper Lake Deposits Upper Glacial Deposits Middle Lake Deposits Lower Glacial Deposits Lower Lake Deposits	a series of interbedded glacial, glaciofluvial and glaciolacustrine deposits
	Lower Drift Unit	sandy till, dirty sands and gravels
Ordovician		
Upper	Whitby Formation	black shale, some inter-bedded limstone
Middle	Lindsay Formation	fine crystalline limestone, with argillaceous beds

From the well logs, it appears that the Oak Ridges Moraine is underlain by a bedrock ridge with an approximate elevation of 500 feet. This ridge may have acted as an ancestral drainage divide, although the lack of data precludes any detailed interpretation.

SURFICIAL DEPOSITS

Surficial deposits in the drainage basin consist of glaciolacustrine, glaciofluvial and glacial sediments of Pleistocene age and alluvium, aeolian, beach, muck and swamp deposits of Recent age. The areal extent of these deposits is shown on Map 4.

Glaciolacustrine Deposits

The glaciolacustrine deposits, representing deposition in proglacial Lake Iroquois, range from coarse-grained, nearshore to fine-grained, offshore sediments.

The coarse-grained, nearshore sediments are deposited in a variety of traceable, linear, lense-like shapes such as bars, spits and beaches. These sediments delineate the now abandoned Lake Iroquois shoreline, a pronounced high-water stand in the Lake Ontario basin (Photo 1). Gravenor (1957) found the abandoned Lake Iroquois shoreline to range from 508-532 feet (msl), from west to east across the basin area. The abandoned shoreline, normally well developed as bluffs in the underlying ground moraine, is obscured in several areas by post-glacial fluvial erosion.

The nearshore lacustrine sediments range from stratified fine sand and silt to well-sorted coarse sand and gravel derived primarily from the underlying ground moraine. Sedimentary structures such as cross and graded-bedding are visible in the string of sand and gravel pits which have been developed along the abandoned shoreline.

A section of nearshore deposits and what appear to be overlying deltaic deposits, exposed in a gravel pit near Stephen's Gulch, are illustrated in the following stratigraphic section and the accompanying photographs (photos 2, 3, and 4).

0 - 10 feet;	stratified sand and gravel (deltaic deposits)
10 - 12 feet;	stratified fine sand
12 - 19 feet;	stratified coarse sand and gravel
19 - 22 feet;	varved silty clay
22 - 40 feet;	stratified, cross-bedded fine sand

The deltaic deposits are assumed to have been formed near the mouth of a stream contemporaneous with and draining into Lake Iroquois.

The fine-grained, offshore deposits (clay ranging to fine sand) occur as sheet-like veneers over the ground moraine. The well-sorted nature of these sediments is illustrated by the varved silt and clay exposed along the Lake Ontario shoreline. There is a general grading from sand and gravel to silt to clay with increasing distance from the abandoned shoreline. The thickness of these materials varies with the underlying relief; more than 20 feet of sediments occur in topographic lows while underlying glacial drift may be exposed on topographic highs such as drumlins.

Clay, silt and fine sand near the community of Enfield were deposited in local pondings of the meltwater between the ice front and the Oak Ridges Moraine. Water-well records for wells in the vicinity of Enfield

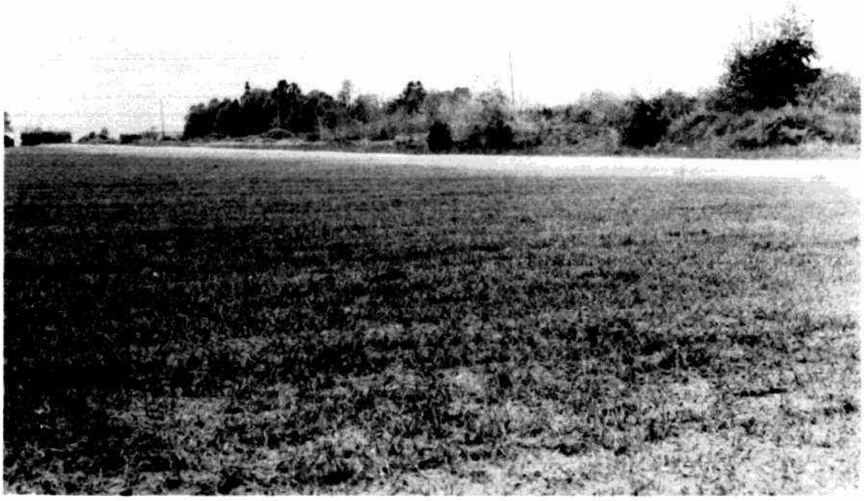


Photo 1. The abandoned Lake Iroquois shoreline west of Orono. This deposit of well-sorted sand and gravel has been extensively quarried.

Photo 2.

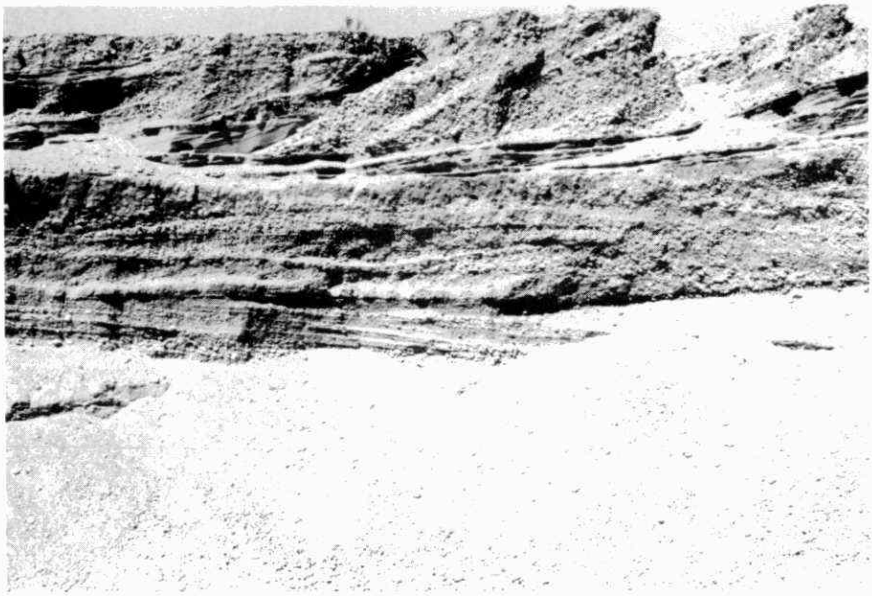


Photo 3.

Photos 2 and 3. Lake Iroquois beach deposits composed of stratified sand and gravel overlain by deltaic sand and gravel, near Stephen's Gulch.

Photo 4. Lake Iroquois sand and gravel deposit near Stephen's Gulch.

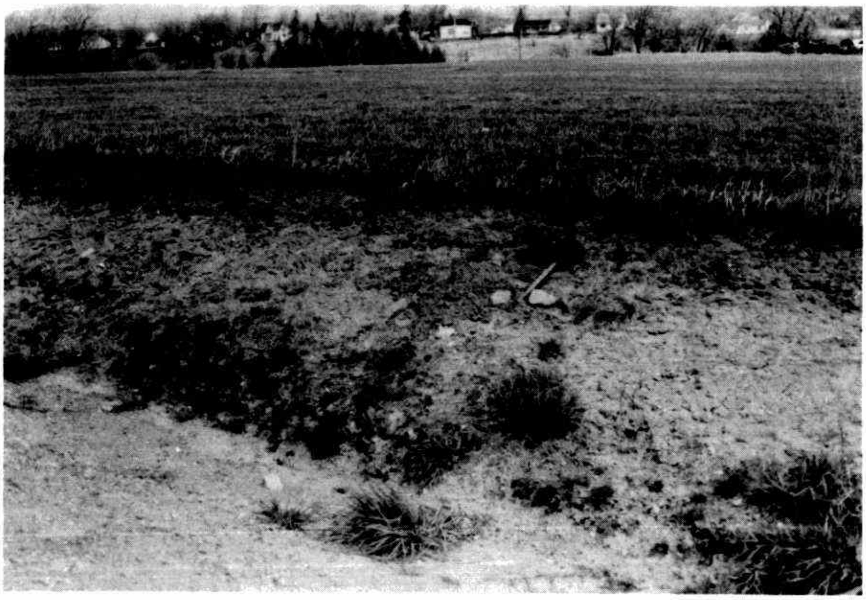


Photo 5. Outwash deposit near the community of Hampton.

Photo 6. Irregular, hummocky accumulations of sand and gravel in the Oak Ridges Moraine.

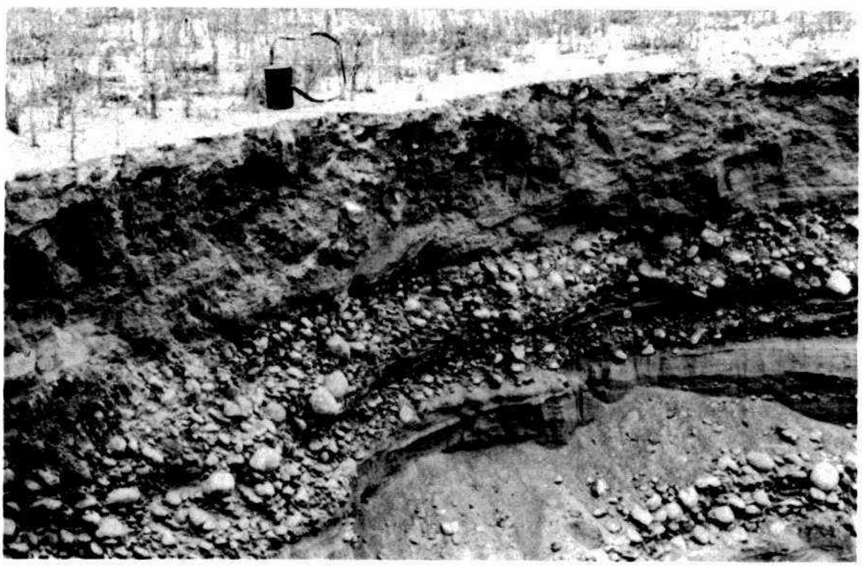


Photo 7. Sandy till, overlying sand and gravel of the Oak Ridges Moraine. This exposure is in a large pit near the northern basin divide.

record thicknesses of about 80 feet of alternating clay and sand which may be attributed to these pondings.

Glaciofluvial Deposits

The glaciofluvial deposits occur as coarse-grained outwash and ice-contact sediments deposited by meltwater flowing off the ice front. A variety of textural and structural features such as cross-bedding, banding and cut and fill structures are present in gravel pits north of the abandoned Lake Iroquois shoreline.

Outwash deposits cover large areas near the communities of Hampton and Orono. These deposits represent materials accumulated and deposited by streams flowing from the Lake Simcoe ice lobe to Lake Iroquois (Gravenor, 1957). Although these deposits are generally only a few feet in thickness, up to several tens of feet of sand and gravel have been recorded in wells finished in local topographic depressions. Photo 5 shows outwash deposits near Hampton.

Irregular, hummocky accumulations of sand and gravel (Photo 6) make up the Oak Ridges Moraine. According to Gravenor (1957), this Moraine was formed between two ice lobes, one in the Lake Ontario basin and advancing from the southeast, and the other occupying much of south-central Ontario and advancing from the northeast. The area between these lobes was covered by great volumes of sand and gravel interbedded with till, resulting from ice-front fluctuations.

The surficial features of the Moraine have been locally modified by the overriding of the Moraine during a brief re-advance of the Lake Simcoe lobe. This ice sheet left a residual cover of up to 40 feet of sandy till. In some instances the underlying sand and gravel deposits have been exposed by aeolian activity, stream erosion, gravel pit activity and road cuts. Sedimentary structural features such as graded- and cross-bedding, in addition to cut and fill features, are common in these road cuts and gravel pits. Photo 7, a gravel pit in the Moraine, shows the sand and gravel with an overlying layer of sandy till.

A few isolated kame deposits occur south of the Oak Ridges Moraine. These deposits represent accumulations of sand and gravel deposited under stagnant ice conditions (Gravenor, 1957).

Glacial Deposits

Glacial deposits of unstratified and unsorted sediments (till) can be found over large portions of the basin in the form of ground moraine and drumlins.

South of the abandoned Lake Iroquois shoreline, the till has been partly reworked by wave action and is veneered by nearshore and offshore lacustrine sediments. The till is commonly a silty, sandy till, becoming increasingly sandier north of the shoreline. This till is visible south of the abandoned shoreline on drumlins (drumloids) which have been wave cut and in other exposures such as road and streamcuts. The orientation of the long axis of these drumlins indicates ice movement to have been locally in a north to northeasterly direction.

North of the shoreline, the ground moraine is locally obscured by outwash deposits and recent aeolian features such as sand dunes.

Recent Deposits

Although sand dunes were not mapped, evidence of wind-blown sand is present in various locations on the Moraine. These deposits consist of one to about 10 feet of fine sand overlying till or kame sand and gravel (photos 8 and 9).

Modern alluvium consists of valley-bottom deposits laid down by fluvial action. The variable composition of these materials is related to the available materials over which the stream flows. Within areas underlain by glaciolacustrine silt and clay deposits, the modern alluvium consists primarily of silt and some clay. Similarly, within the areas mantled by sand deposits, the alluvium consists of locally derived sand. Other recent deposits are the Lake Ontario beach deposits.

The bog and swamp deposits represent the infilling of depressions by organic debris. In the Bowmanville, Soper and Wilmot creeks basin, the only bog and swamp deposits with significant thicknesses occur along Lake Ontario at the mouth of the creeks (Photo 10).

STRATIGRAPHY ALONG THE LAKE ONTARIO SHORELINE

The stratigraphic sequence as described by Singer (1973, 1974) for the exposed sections along the Lake Ontario bluffs in the Bowmanville-Newcastle area is presented in Table 5.

TABLE 5. STRATIGRAPHIC SEQUENCE FOR THE BOWMANVILLE-NEWCASTLE AREA, AFTER SINGER (1974)

Stage	Stratigraphic Unit
Recent	Lake Ontario Deposits, Swamp and Bog Deposits
Late Wisconsinan	Proglacial Lake Unit Upper Glacial Unit Middle Glacial Unit
Middle Wisconsinan	Clarke Deposits Unit
Early Wisconsinan	Lower Glacial Unit

These units are not continuous along the bluffs, as one or more units may be missing from any one section. The stratigraphic column is therefore a composite of the various sections and presents the stratigraphic relationships of these units (Singer, personal communication). The reader is referred to Singer (1973,1974) for a detailed description of the units encountered along the Lake Ontario shoreline.

STRATIGRAPHY NORTH OF THE LAKE ONTARIO SHOREBLUFFS

The stratigraphic and lithologic sequence as inferred from the logs of the Ministry of the Environment observation wells completed north of the Lake Ontario shoreline is presented in Table 6. The MOE well logs are included in Appendix B.

Table 7 and Figure 2 present the mechanical and carbonate analyses for samples obtained from the observation wells.

The overburden geology north of the Lake Ontario shoreline has been

Photo 8. Wind-blown sand in the South Slope.

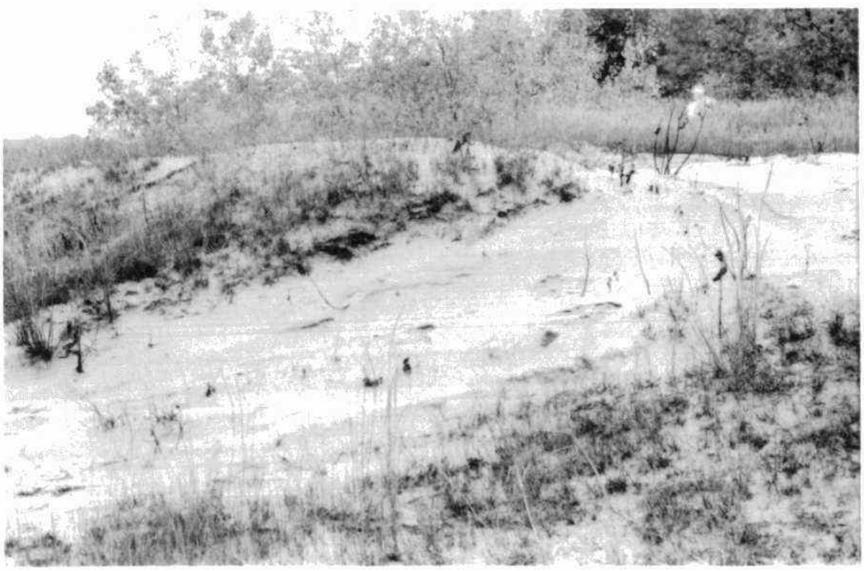


Photo 9. Wind-blown fine sand in the South Slope.

tentatively divided into three units representing the Early, Middle and Late substages of the Wisconsinan Stage, and deposits representing the Recent Stage. The time correlations are relative, being based on similarities in stratigraphic sequence with units in the Scarborough area.

TABLE 6. STRATIGRAPHIC AND LITHOLOGIC SEQUENCE AS INFERRED FROM WELL LOGS AND EXPOSURES IN THE AREA NORTH OF THE LAKE ONTARIO SHOREBLUFFS.

	Epoch, Stage and Substage	Stratigraphic Unit	Lithology and Origin
	Recent Stage	Recent Sediments	Swamp, bog, alluvium and aeolian sediments (gravel, sand, silt, clay, muck)
PLEISTOCENE EPOCH WISCONSINAN STAGE	Late Substage	Lake Iroquois Deposits	Beach, near and offshore sediments (gravel, sand, silt and clay)
		Upper Drift Unit	Glacial and glaciofluvial sediments (till, gravel, sand and silt)
	Middle Substage	Middle Drift Unit Upper Lake Deposits Upper Glacial Deposits Middle Lake Deposits Lower Glacial Deposits Lower Lake Deposits	Glacial, glaciofluvial and glaciolacustrine sediments (till, gravel, sand, silt and clay)
	Early Substage	Lower Drift Unit	Glacial, minor glaciofluvial sediments (till, gravel, sand. silt and clay)

Early Substage

The Early Substage, directly overlying the bedrock, consists of glacial and glaciofluvial sediments of the Lower Drift Unit. This unit has only been identified in the Oak Ridges Moraine where it ranges in thickness from 40 feet in well W-2 and 43 feet in well W-10 to 50 feet in W-8. The upper contact is drawn below a glaciolacustrine layer representing the Lower Lake Deposits of the Middle Drift Unit.

Mechanical analyses for four samples of till from observation wells W-2 and W-8 averaged 5 percent clay, 9.5 percent silt and 85.5 percent sand. The matrix material for six samples averaged 21.9 percent calcite and 6.8 percent dolomite with a calcite-dolomite ratio of 3.1. This till is sandier than the overlying tills of the Middle and Upper Drift Units (Table 7).

Middle Substage

The Middle Substage is composed of a sequence of interbedded glacial, glaciofluvial and glaciolacustrine sediments of the Middle Drift Unit. The Middle Drift Unit is sub-divided into three separate glaciolacustrine and associated glaciofluvial (deltaic) deposits (Lower,

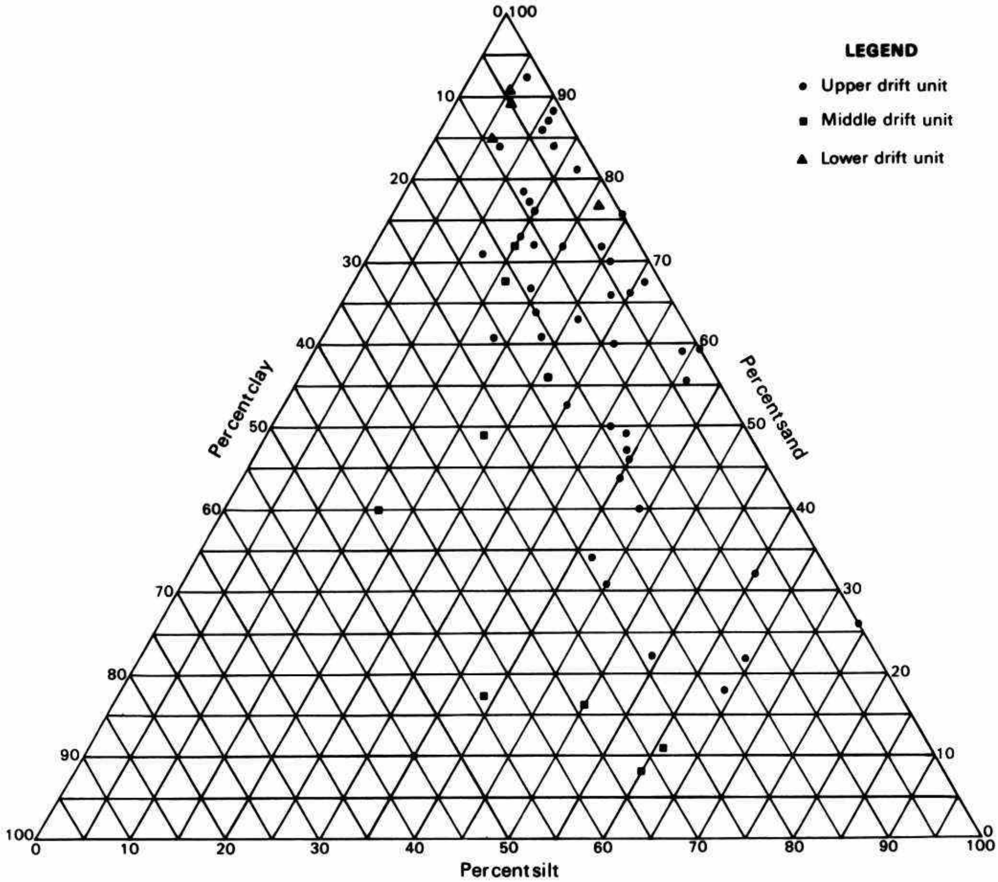


Figure 2. Graphic plot of the mechanical analyses conducted on observation-well overburden samples.

Photo 10. Marshy area at the mouth of Bowmanville Creek.

TABLE 7. COMPARISON OF MECHANICAL AND CARBONATE ANALYSES OF VARIOUS UNITS IN THE SCARBOROUGH AREA EASTWARD TO THE BOWMANVILLE-NEWCASTLE AREA

Units and/or Formation	Report (Source)	Location	Mechanical Analyses (%) # of Samples	Clay	Silt	Sand	Carbonate Analyses (%) # of Samples	Calcite	Dolomite	Total	Calcite/Dolomite Ratio
Lower Till(s)											
York Till	Karrow (1967)	Rouge River	3(?)	30	23	47	3?	22	6	28	3.7
York Till	Ostry (1962)	Scarborough	2	23	22	55	2	16	5	21	3.2
Lower Drift (iv)	Sibul et al (in press)	Duffins-Rouge Basin	7	14	20	66	7				4.6
Sunnybrook Till	Karrow (1967)	Scarborough	29	45	37	18	22	6	6.5	12.5	0.9
Till No. 1	Ostry (1962)	Scarborough	12	50	32	18	12	14	7	21	2.0
Interstadial Drift (iii)	Sibul et al (in press)	Duffins-Rouge Basin	4	36	42	22					2.4
Lower Glacial Unit	Singer (1974)	Bowmanville-Newcastle Area	9	31.6	51.6	16.8	9	21.0	7.1	28.1	2.9
Lower Drift Unit	This report	Observation wells in drainage basin	4	5	9.5	85.5	6	21.9	6.8	28.7	3.1
Middle Till(s)											
Seminary Till	Karrow (1967)	Scarborough	8	33	30	37	8	18	7	25	2.7
Till No. 2	Ostry (1962)	Scarborough	1	26	18	56	1	19	7	26	2.7
Meadowcliffe Till	Karrow (1967)	Scarborough	9	54	35	11	9	24	6	30	4
Till No. 3	Ostry (1962)	Scarborough	1	48	37	17	1	26	6	32	4.3
Middle Drift (ii)	Sibul et al (in press)	Duffins-Rouge Basin	27	27	40	33					3.2
Middle Glacial Unit	Singer (1974)	Bowmanville-Newcastle Lakeshore	4	32.4	53.9	13.7	4	34	6.5	40.5	5.5
Middle Drift Unit	This report	Observation Wells	(5)	(36)	(45)	(19)	4	29.7	8.7	38.4	3.4
		Drainage Basin	9*	28	34	38	7*	30.5	9.1	39.6	3.3
Upper Till											
Leaside Till	Karrow (1967)	Scarborough	46	20	33	47	25	25	6	31	4.0
Till No. 4 & 4a	Ostry (1962)	Scarborough	5-#4A	20	28	52	5	32	5	37	6.4
		Scarborough	11-#4	19	33	48	11	28	7	35	4.0
Upper Drift (i)	Sibul et al (in press)	Duffins-Rouge Basin	43	22	33	48	40				5.3
Upper Glacial Unit	Singer (1974)	Bowmanville-Newcastle Area	18-Upper Till	12.3	37.0	30.7	18	39.3	6.1	45.4	6.5
		Shoreline	14-Lower Till	12.6	38.4	49.0	15	36.5	7.0	43.5	5.2
Upper Drift Unit	This Report	Observation Wells Drainage Basin	47-Undiff.	9.8	28.2	62	47	39.7	6.7	46.4	6.7

*Four anomalous samples included (from a well completed by mud rotary drilling procedures).

Middle and Upper Lake Deposits) by two tills (Upper and Lower Glacial Deposits). The section of the geological log of observation well W-10, used in making this subdivision, is as follows:

Unit	Lithological Description	Depth	Deposit
	silty clay with sand	384-396	Upper Lake Deposits
	dense clay	396-416	
Middle	clay silty till	416-498	Upper Glacial Deposits
Drift	clay till	498-508	
Unit			
(W-10)	gravel with clay and till		
	minor till (523-526)	508-556	Middle Lake Deposits
	clay till	556-621	Lower Glacial Deposits
	silty sand	621-636	Lower Lake Deposits

In well W-8, the Middle Drift Unit is composed of a single till layer (235 feet thick) sandwiched between two thin glaciolacustrine layers (8 and 20 feet thick). The Middle Drift Unit in well W-2 is thinner, consisting of approximately 30 feet of till between two glaciolacustrine layers (80 and 10 feet thick). The Middle Drift Unit could only be identified in wells in the Oak Ridges Moraine and South Slope areas but is assumed to be continuous with Singer's Clarke Deposits Unit to the south.

Mechanical analyses for five till samples of this Unit averaged 36 percent clay, 45 percent silt and 19 percent sand. Seven carbonate analyses averaged 29.7 percent calcite and 8.7 percent dolomite with a calcite-dolomite ratio of 3.4.

The upper contact of the Unit is below the sandy till of the Upper Drift Unit.

Late Substage

The Late Substage is divided into the Upper Drift Unit, a sequence of interbedded glacial and glaciofluvial sediments and the Lake Iroquois Deposits which have been previously mentioned. The Upper Drift Unit has a maximum recorded thickness of approximately 380 feet in the Oak Ridges Moraine. This Unit thins to only a few tens of feet along the Lake Ontario shoreline.

The glacial sediments grade from a sandy till in the Oak Ridges Moraine where underlying glaciofluvial materials have been overriden and incorporated into the texture, to a silty sand till south of the abandoned Lake Iroquois shoreline, where this till has been reworked by wave action.

The glaciofluvial sediments of this Unit range in thickness from 325 feet in the Oak Ridges to a few feet in the area south of the abandoned Lake Iroquois shoreline. These sediments are well-sorted and are being commercially used as an aggregate source.

A total of 47 till samples were analysed. These samples averaged 9.8 percent clay, 28.2 percent silt, and 62 percent sand. The results of these analyses are presented in Figure 2. The carbonates averaged 39.7 percent calcite and 6.7 percent dolomite with a calcite-dolomite ratio of 6.7.

TABLE 8. TENTATIVE CORRELATION OF THE STRATIGRAPHIC UNITS ENCOUNTERED IN THE RESPECTIVE AREAS

Scarborough Section (Karrow, 1967)		Lake Ontario Basin (Dreimanis and Karrow, 1972)	Duffins Area (Ostry, in press)	Duffins-Rouge basin (Sibul, et al in press)	Bowmanville-Newcastle Section (Singer, 1974)	Bowmanville, Wilmot and Soper creeks basin (this report)
Stage	Formation or Event	Formation				
RECENT	Lake Ontario beaches Alluvium Swamp and bog deposits Stream terrace deposits				Lake Ontario Deposits Swamp and Bog Deposits	Lake Ontario Deposits Alluvium Swamp and Bog Deposits Aeolian Deposits
WISCONSINAN Late	Lake Iroquois Early peripheral lakes	Lake Iroquois Deposits	Lake Iroquois Deposits		Proglacial Lake Unit	Lake Iroquois Deposits
	Leaside Till Lake and stream deposits	Upper Leaside Till Lower Leaside Till	Upper Leaside Till Lower Leaside Till	i. Upper Drift	Upper Glacial Unit	Upper Drift Unit
	Meadowcliffe Till Lake and stream deposits Seminary Till				Middle Glacial Unit	
Middle	Thorncliffe Formation	Upper Thorncliffe Lake Beds Meadowcliffe Till Lower Thorncliffe Lake Beds Seminary Till Lower Thorncliffe Lake Beds	Late Lake phase Meadowcliffe Till Intermediate Lake phase Seminary Till Early Lake phase	ii. Middle Drift iii.Interstadial Drift	Clarke Deposits Unit	Middle Drift Unit: Upper Lake Phase Middle Lake Phase Lower Lake Phase
Early	Sunnybrook Till Scarborough Formation	Sunnybrook Till Channel Sands Valley Erosion Scarborough Formation	Sunnybrook Till not identified		Lower Glacial Unit not present	Lower Drift Unit
SANGAMONIAN	Don Formation	Don Formation	not identified	not identified	not present	not identified
ILLINOIAN	York Till	York Till	not identified	iv. Lower Drift	not present	not identified

COMPARATIVE STRATIGRAPHY

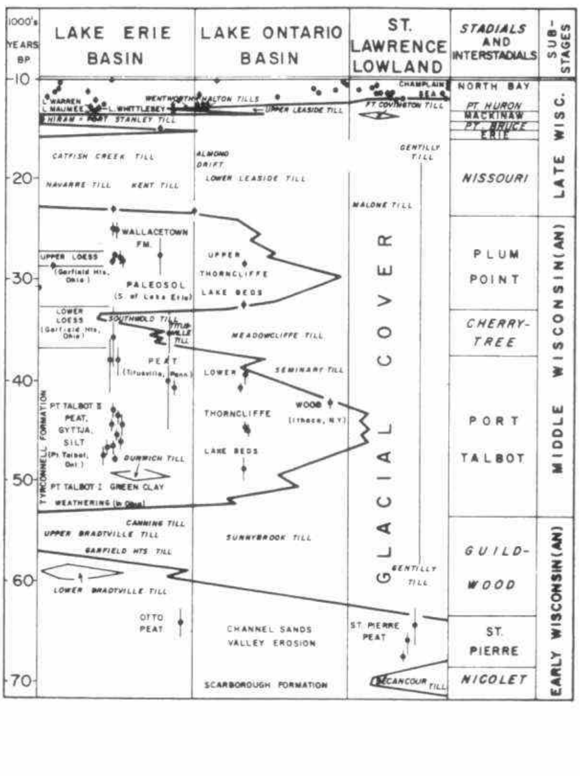
The stratigraphic units encountered in the study area appear to be compatible with those found to the west (Karrow, 1967; Ostry, 1962 and in press; Sibul et al, in press) and with those found along the Lake Ontario shoreline (Singer, 1973, 1974). Table 7 presents a comparison of mechanical and carbonate analyses of various units in the Scarborough area eastward to the Bowmanville-Newcastle area and northward to the Oak Ridges Moraine. Similarly, Table 8 is a tentative correlation of the overburden stratigraphy as interpreted in the respective areas. These units are correlated on the basis of stratigraphic position and textural composition.

GLACIAL HISTORY

The glacial history of this area has been described by Coleman (1936), Gravenor (1957), Chapman and Putnam (1966), and Dreimanis and Karrow (1972). Table 9, after Dreimanis and Karrow, is a time-space diagram relating the stratigraphy of the Great Lakes-St. Lawrence Region with time-stratigraphic divisions.

The glacial and non-glacial deposits of the study area can be related to this table by comparison with Table 8. No Pre-Wisconsinian deposits have been identified in the study area.

TABLE 9. TIME-SPACE DIAGRAM RELATING THE STRATIGRAPHY OF THE GREAT LAKES - ST. LAWRENCE REGION WITH TIME-STRATIGRAPHIC DIVISIONS (AFTER DREIMANIS AND KARROW, 1972)



GROUND WATER RESOURCES

The following sections present a discussion of the hydrogeologic environment of the BSW drainage basin and its relationship to the occurrence, availability, quality and renewability of the ground-water resources within the basin. This analysis is based on data obtained from water wells (Map 5), hydrologic and meteorological records, and detailed field mapping and water quality surveys.

HYDROGEOLOGIC UNITS WHICH CONSTITUTE THE MAJOR AQUIFERS

The hydrogeologic units which constitute the major aquifers in the drainage basin are listed below (Table 10) under the physiographic region in which they are found. These are described in more detail later in this study.

TABLE 10. HYDROGEOLOGIC UNITS WHICH CONSTITUTE THE MAJOR AQUIFERS IN THE BASIN

Lake Iroquois Plain	South Slope	Oak Ridges Moraine
Abandoned Lake Iroquois beach and nearshore deposits	Glaciofluvial sand and gravel of the Upper Drift Unit	
Glaciofluvial and glaciolacustrine sand and gravel of the Middle Drift Unit		
Channel sand and gravel situated in bedrock lows and ancestral drainage channels (possibly Lower Drift Unit)		

Neither the till nor the underlying bedrock units, although water-bearing and locally productive, are considered to be major aquifers because of the low yields generally obtained for the wells finished within these geologic materials.

HYDROGEOLOGIC CHARACTERISTICS OF THE BEDROCK AND OVERBURDEN

Bedrock

For the most part the carbonate and shale bedrock underlying the study area is obscured by overburden deposits. Only a small portion of the total number of wells are completed in the bedrock, largely because of the availability of ground water from the many shallower, sand and gravel horizons in the overburden. Most of the bedrock wells are found south of the Lake Iroquois shoreline where the overburden is either too thin or of such low permeability that it cannot sustain a domestic water supply.

Ground water occurs in fractures, joints and bedding-plane openings in the bedrock. The quantity of ground water available for use is directly related to the number of openings encountered by the well and the degree of interconnection of these openings. The bedrock exposed in the St. Mary's Quarry just west of Bowmanville has both horizontal and vertical fractures. There is very little seepage from these openings, suggesting that the permeability of the bedrock is low.

Overburden

The overburden is composed of a variety of unconsolidated materials ranging in grain size from clay to gravel. Ground water is present in the pore spaces between individual grains. The quantity available for use is dependent on the size, sorting and compaction of these grains (porosity) and the degree of interconnection of the pore spaces between the grains (permeability). Geologic units or formations, such as well-sorted sands and gravels, which are sufficiently porous and permeable to supply ground water at a continous rate, are called aquifers. Fine-grained units such as clays, although highly porous, have low permeabilities and do not yield water readily. These units are called aquitards. Similarily, poorly sorted tills which have low porosities and permeabilities also act as aquitards.

DESCRIPTIVE HYDROGEOLOGY OF THE PHYSIOGRAPHIC SUBDIVISIONS

Oak Ridges Moraine

The Oak Ridges Moraine acts as both the drainage divide and source area for north and south flowing streams in this part of Ontario. The hilly, knob and kettle topography composed of sandy till and glaciofluvial sand and gravel has been sharply altered by wind and water erosion since deposition. The permeable overburden materials allow for the rapid infiltration of precipitation, thereby almost eliminating the surface runoff contribution to streams in the area. Precipitation, for the most part, drains vertically until it reaches beds or units of lower permeability where it then migrates laterally. Ground-water discharges in the form of seepages and springs occur along the sharp topographic break of the south slope of the Moraine and along incised stream valleys within the Moraine. These contribute the main source of water to the streams.

The thick glaciofluvial deposits which are present in the Oak Ridges Moraine and interfinger with the tills of the South Slope physiographic region, constitute one of the largest aquifer complexes in south-central Ontario. Thicknesses of up to 325 feet of sand and gravel have been measured in the MOE observation wells finished in the Oak Ridges Moraine. The saturated portion of the sand and gravel measures almost 170 feet.

The Oak Ridges aquifer complex is typically under unconfined ground-water conditions in areas where the sand and gravel is exposed in the Moraine. To the south, and locally where these deposits are blanketed with till, the ground water is under confined conditions, the static water level being higher than the elevation at which water is first encountered in the well when constructed. Perched water tables occur locally as a result of till and clay lenses; these create anomalous water levels in wells which encounter these lenses, when compared to the continuity of the aquifer unit and the head potential measured in wells finished in the Oak Ridges aquifer complex. The measured static water levels in wells finished in the Moraine range from 30 to 180 feet below the surface, depending on local topographic irregularities. The Oak Ridges aquifer complex extends southward until it pinches out between the tills of the Upper and Middle Drift Units. A north-south cross section through the basin shows the southward extension of the sand and gravel (figures 3 and 4) while an east-west cross section presents its lateral extent within the basin (Figure 5).

The sandy-silty tills which underlie and are interbedded with the Oak Ridges aquifer complex act as aquitards. As indicated earlier these create confined artesian conditions in the South Slope region.

A series of discontinuous glaciofluvial and glaciolacustrine sand, gravel, silt and clay beds and lenses are found at depth in the Moraine. These are tentatively identified as having been deposited during brief interstadial periods and appear to be traceable southward to the Lake Ontario shoreline where Singer (1974) labelled them as Clarke Deposits. The saturated sand and gravel fractions of these deposits are not used in the Oak Ridges Moraine area for water-supply purposes because of the ample water supply obtainable from shallower sand and gravel. They do, however, act as important aquifers in the South Slope and Lake Plain regions.

South Slope

The South Slope is an area of high relief. The overburden consists primarily of silty till, although sand and gravel lenses and beds are encountered in most wells. There are many productive and potentially productive water-bearing zones. These zones are often continuous with the glaciofluvial deposits of the Oak Ridges Moraine. Figure 5 shows an east-west cross section through the South Slope region illustrating the many sand and gravel deposits or aquifer zones.

The South Slope is largely overlain by tills creating confined conditions. A number of flowing wells are present along both stream valleys and where confined lenses of glaciofluvial sediments under considerable hydrostatic pressure are encountered during well drilling. Seepages and springs are common where sand and gravel lenses outcrop along valley walls. The Town of Bowmanville obtains a portion of its water supply from one of these springs in the Tyrone area.

Lake Iroquois Plain

The Lake Iroquois Plain situated south of the abandoned Lake Iroquois shoreline is the most heavily populated of the three physiographic areas, with the communities of Orono, Newcastle and Bowmanville. These communities obtain their water supplies from local aquifers, ground-water seepages, streams and Lake Ontario.

Based on water-well records, at least four areas with potentially favourable aquifers occur in the vicinity of these communities. These aquifers are as follows:

1. Extensive sand and gravel deposits underlying Orono and extending to the north and south. Up to 105 feet of continuous sand and gravel occur at depth. These coarse-grained sediments are assumed to have been deposited during glaciolacustrine intervals of the Middle Wisconsinan Substage. In addition, the surface deposits consist of beach terraces of the abandoned Lake Iroquois shoreline ranging up to 25 feet in thickness.
2. Sand and gravel beds centred on Stephen's Gulch and extending southwards for about two miles. These deposits have a continuous thickness of approximately 100 feet. Although their origin is uncertain, it is believed that they represent a combination of beach remnants from the abandoned Lake Iroquois

shoreline, deltaic deposits formed at the mouth of a stream which was concurrent with Lake Iroquois and the previously-mentioned glaciolacustrine sediments of the Middle Wisconsinan Substage.

3. A deposit of sand and gravel located near Maple Grove just west of the drainage boundary in the vicinity of Bowmanville. In this area up to 70 feet of sand and gravel have been encountered in wells. The boundaries of this aquifer are poorly defined; however, it is assumed that it extends both to the north and the south for a distance of two to three miles. The origin of this deposit is assumed to be similar to that of #2.
4. Channel sand and gravel deposited in bedrock lows and supplying the water needs of Newcastle. This deposit which underlies Newcastle ranges in thickness from 1 to 43 feet. Similar deposits occur in ancestral drainage channels in other parts of the Lake Plain.

Singer (1974) conducted a comprehensive study in the Lake Iroquois Plain. Additional information on this region may be obtained from his report.

HYDRAULIC PROPERTIES OF THE BEDROCK AND OVERBURDEN

The hydraulic properties of the bedrock and the overburden can be expressed quantitatively by using descriptors such as the coefficients of transmissibility, permeability and storage. These values can be estimated for various water-bearing materials in the basin by using one of the following methods:

1. pumping and recovery tests,
2. estimation of transmissibility from specific capacity values obtained during short-term pumping tests,
3. empirical relationship between grain-size distribution and permeability,
4. baseflow analysis.

Pumping and Recovery Tests

These tests, in which the effects of pumping are measured in the pumped wells and in nearby observation wells, can be used in arriving at reasonable estimates of the coefficients of transmissibility, permeability and storage. The results of tests conducted by MOE personal and consultants hired by the MOE for the purpose of aquifer evaluation, are presented in Table 11. Locations, maps and geological logs for these tests are included in Appendix C.

The permeability and transmissibility of the bedrock were estimated by Singer (1974) from short-term pumping tests. The permeability values of the limestone ranged from 0.1 to 38 Igpd/ft^2, averaging 8 Igpd/ft^2, while a single value obtained for the shale was 0.02 Igpd/ft^2. The mean transmissibility for the upper 50 feet of the bedrock, both limestone and shale, was 1800 Igpd/ft. The domestic wells giving these values obtained water primarily from the upper portion of the bedrock which is assumed to be more intensely fractured and chemically weathered. No long-term pumping tests were conducted on wells finished in the bedrock.

The coefficient of storage in the vicinity of the pumped wells as based on the pumping tests (Table 11) averaged 9×10^{-4} for the till, and 6×10^{-5} for the sand and gravel near Newcastle. The coefficient of

TABLE 11. HYDRAULIC CHARACTERISTICS BASED ON PUMPING TESTS FOR WELLS IN THE STUDY AREA

Location	Source of Information	Aquifer Unit/ Material	Study Area Pumped Well #	Study Area Obser. Well #	Pumping Rate	Test Length	Coefficients Determined: Transmissibility Igpd/ft	Coefficients Determined: Permeability Igpd/ft²	Coefficients Determined: Storage	Comments
Oak Ridges	OWRC, 1967	Upper Drift Unit-till	W-9	W-8	14 Igpm	85 min.	74	18		No change in MOE observation well.
South Slope	OWRC, 1967	Upper Drift Unit-till	W-5B	W-5a	1.5 Igpm	81 min.	73	8	$6x10^{-4}$	No change in MOE observation well.
Lake Plain	OWRC, 1967	Upper Drift Unit-till	S-6a	S-6b	7 Igpm	200 min.	573	57	$1.2x10^{-3}$	No change in MOE observation well.
Newcastle	OWRC, 1967	Lower Drift Unit (?) Channel Sand/Gravel	MW		150 Igpm	24 hr.	5500			Value estimated from 19.4' drawdown over 24 hrs.
Newcastle	Hydrology Con. Ltd. ('71)	Lower Drift Unit (?) Channel Sand/Gravel	TW6/71		20 gpm	90 min.	1000-1500	250-375		Poor aquifer conditions to east and west of site.
Newcastle	Hydrology Con. Ltd. ('71)	Lower Drift Unit (?) Channel Sand/Gravel	TW13/71	TW12/71	50 gpm	24 hr.	2500	320	$3x10^{-5}$	Flowing well conditions.
Newcastle	Hydrology Con. Ltd. ('71)	Lower Drift Unit (?) Channel Sand/Gravel	TW16/71	TW6/71 MW1	45 gpm	24 hr.	4500	1125		
Newcastle	Ian D. Wilson & Assoc.('74)	Lower Drift Unit (?) Channel Sand/Gravel	MW2		70 Igpm	10-100 min.	4200	525		
Newcastle	Ian D. Wilson & Assoc.('74)	Lower Drift Unit (?) Channel Sand/Gravel	MW2	TW12/71	70 Igpm	50-500 min.	5400			
Newcastle	Ian D. Wilson & Assoc.('74)	Lower Drift Unit (?)	MW2	TW13/71	70 Igpm	100-1000 min.	4700		$1x10^{-4}$	
Orono	Hydrology Con. Ltd.('65)	Upper & Middle Drift Unit Sand/Gravel	PW1-65	TW5-60 TW6-60	75.6 Igpm	72 hr.	7500	750	$1.5x10^{-5}$	
Orono	OWRC, 1960	Upper & Middle Drift Unit Sand/Gravel	TW8-60	TW9-60 TW9-60	31 Igpm	12 hr.	15400	810	$2x10^{-6}$	Drilling and pump tests conducted by International Water Supply ('60)
Orono	Ian D. Wilson & Assoc. ('75)	Upper & Middle Drift Unit Sand/Gravel	PW1-74	TW8-60	100 Igpm	72 hr.	35200		$7.5x10^{-5}$ to $1.0x10^{-8}$	Observation wells; consultants estimated values using synthetic and available data.

Hydrology Consultants Ltd. (1965). Report on Pumping Tests for the Village of Orono. OWRC Project No. 64-W-130, by T. M. Kerr.
.... (1971). Report on Test Drilling for a Ground Water Source of Supply for the Village of Newcastle, by W. D. Morrison.
Ian D. Wilson & Associates (1974). Report on Well Construction, Village of Newcastle, MOE Project No. 6-0212-70.
.... (1975). Town of Newcastle, Orono, Well Construction, MOE Project No. 6-0233-71.
OWRC, (1960, 1967) "In House" Ground Water Evaluation Report.

MW - municipal Well PW - pump well TW - test well

storage for the sand and gravel in the Orono area ranged from 1.5×10^{-5} to 1×10^{-8}. These storage values are in the order of those obtained for confined aquifers (Todd, 1959).

Estimation of Transmissibility from Specific Capacity Values

Rough estimates of transmissibility can be obtained from specific-capacity values calculated from short-term pumping test data presented in water-well records. The specific capacity of a well is the rate at which the well is pumped (gallons per minute) divided by the drawdown (feet). The specific-capacity values used in this study were adjusted to a common well radius of 6 inches and a pumping time of one hour.

The relationship between the transmissibility and the specific capacity of a well as presented and discussed in Theis et al (1963) is illustrated in Figure 6. This linear relationship presented in this graph is for a well diameter of 0.5 feet, pumping interval of approximately one hour and storage coefficients of 0.1 and 2×10^{-5}. The transmissibility values thus obtained are presented in Table 12. These values are of the same magnitude as those obtained from the pumping tests.

TABLE 12. TRANSMISSIBILITY VALUES FROM SPECIFIC CAPACITIES

Geologic Material	# of Samples	Specific Capacity (Igpm/ft)		Estimated Transmissibility (Igpd/ft)
Overburden				
Upper Drift Unit-sand	371	1.34	mean	3400
and gravel		(0.01-12.2)	range	(20-40,000)
Channel sand	66	0.60	mean	1500
and gravel		(0.01-2.6)	range	(20-7,000)
Upper Drift Unit-till	16	0.42	mean	1050
		(0.01-2.3)	range	(20-6,000)
Bedrock				
limestone	85	0.30	mean	730
		(0.01-3.3)	range	(20-8,500)
shale	8	0.09	mean	230
		(0.05-0.2)	range	(120-500)

Empirical Relationship between Grain-Size Distribution and Permeability

The permeability of uniformly graded material can be estimated from grain-size analyses (Todd, 1959; Hough, 1957). The method attributed to Hazan (Hough, 1957) was used in this study. This method assumes a linear relationship between the effective grain size (d_{10}) and permeability. The effective grain size d_{10} is defined as the particle size where 10% of the material is "finer than".

Figure 7 presents the graphical plot of permeability versus effective grain size for the values presented by Hough. Permeability values obtained for sand and gravel samples collected within the study area were extrapolated from the graph. Table 13 presents the grain-size

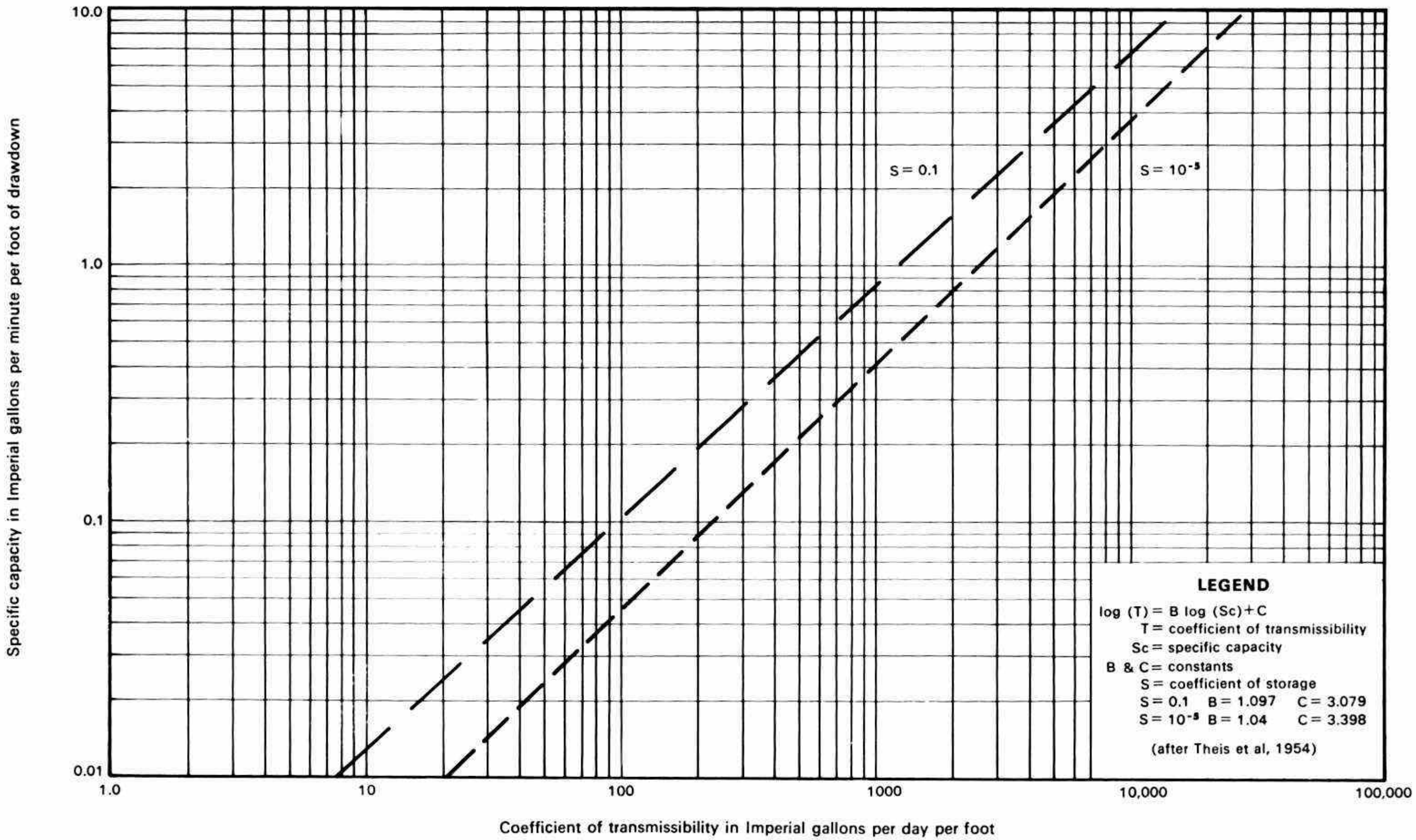


Figure 6. Relationship between specific capacity and the coefficient of transmissibility.

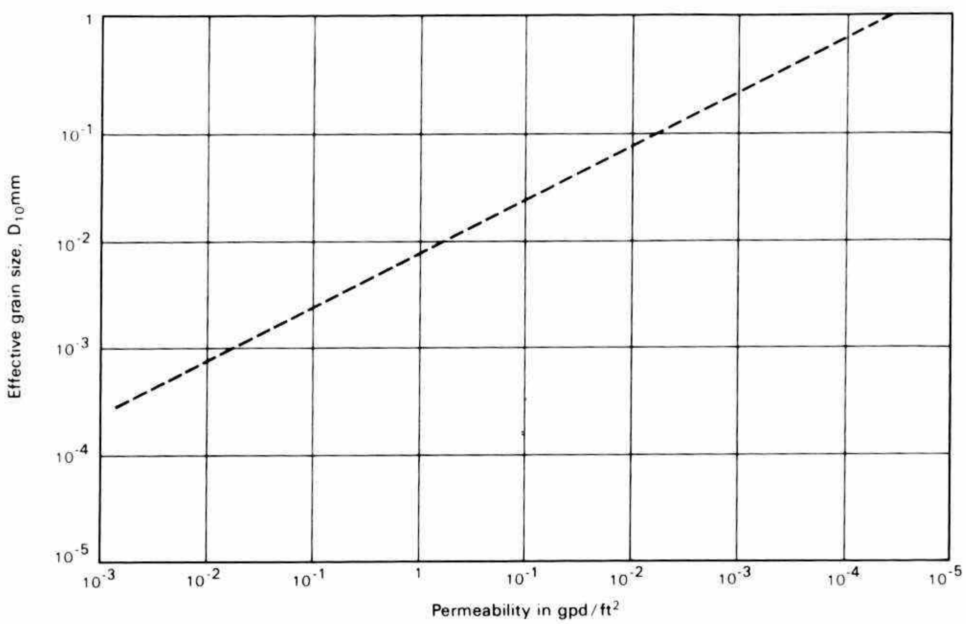


Figure 7. Graphic relationship between values of permeability and effective grain size of various soil types (after Hough, 1957).

distribution of the samples, their effective grain size and the estimated permeability values (K).

Permeabilities obtained from grain-size distribution estimates by Singer (1974) are included for comparison on Table 13. These samples were collected along the Lake Ontario shoreline.

The permeability values obtained by this method should be regarded only as rough estimates of the actual values. The permeabilities obtained for the silt of the Lake Ontario shoreline bluffs ranged from 4.0 to 15 Igpd/ft^2, for the sand of the South Slope and Lake Ontario shoreline bluffs 12.0 to 810 Igpd/ft^2 and for the sand and gravel of the Oak Ridges Moraine 85 to 10,000 Igpd/ft^2. These values are compatible with those obtained in the pumping tests which for the sand and gravel from the Orono and Newcastle areas ranged from 250 to 1125 Igpd/ft^2.

Estimation of Transmissibility from Baseflow Analysis of Streamflow

The mean transmissibility for a specific area can be estimated from the ground-water contribution to the stream segment which transgresses that area. Ground-water flow into the stream is governed by Darcy's Law as follows:

$$Q = 2\ TIL$$

where:

- Q = the ground-water contribution to the streams from both sides of the stream (stream baseflow),
- T = mean transmissibility of the geologic materials through which ground water moves on its way to the stream,
- L = length of the stream segment (value multiplied by two to simulate flow from both sides of the stream),
- I = mean hydraulic gradient towards the stream.

Singer (1974) applying Darcy's Law to the Bowmanville and Wilmot creeks sub-basins estimated the average transmissibility of both areas transgressed by the creeks to be in the order of 1300 Igpd/ft. Singer considered these values to largely represent the transmissibility of the overburden because they are in fair agreement with those determined from short-term pumping tests (1600 Igpd/ft). Both transmissibility values, 1300 Igpd/ft and 1600 Igpd/ft (Singer, 1974) are compatible with the transmissibility values calculated from specific capacities and pump tests in this study.

GROUND WATER MOVEMENT

Ground-water movement within the basin is governed by the distribution of the hydraulic potential of the ground water at any given point in the basin. Hubbert (1940) defined the hydraulic potential as follows:

$$\Phi = g\,z + (p_1 - p_0)/\delta$$

where:

- Φ = hydraulic potential at a given point,
- g = acceleration due to gravity,
- z = elevation (at the given point) above a standard horizontal datum,
- p_0 = atmospheric pressure,
- p_1 = pressure at the given point,
- δ = density of the water.

TABLE 13. PERMEABILITY VALUES ESTIMATED FROM GRAIN SIZE ANALYSES

Well No.	Well Depth Sample No.	% Grain Size Sand	Silt	Clay	Effective Grain Size d_{10} mm	Permeability K in Igpd/ft^2	Material
SAND, SILT AND GRAVEL IN THE SOUTH SLOPE REGION							
W-5a	0-12'	59.5	40.5	0.0	$3.2x10^{-2}$	7.5	silty sand
W-5a	41-45'	95.9	4.1	0.0	$3.5x10^{-1}$	810	sand and gravel
W-56	38-48'	99.5	0.5	0.0	$3.0x10^{-1}$	710	sand and gravel
W-5a	61-72'	25.9	74.1	0.0	$1.7x10^{-2}$	4.5	sandy silt
SAND AND GRAVEL OF THE OAK RIDGES MORAINE							
W-8	225'	100	0.0	0.0	$4.5x10^{-1}$	1000	sand and gravel
W-8	295'	100	0.0	0.0	$9.0x10^{-2}$	100	fine sand
W-8	360'	100	0.0	0.0	$7.6x10^{-2}$	85	fine sand
W-9	50'	100	0.0	0.0	$3.5x10^{-1}$	780	sand and gravel
W-9	60'	100	0.0	0.0	$2.6x10^{-1}$	680	medium sand
W-9	100'	100	0.0	0.0	$2.1x10^{-1}$	500	medium sand
W-9	154.5'	100	0.0	0.0	$9.0x10^{-1}$	10000	coarse sand and gravel
W-9	225'	100	0.0	0.0	$1.6x10^{-1}$	420	medium sand and gravel
W-9	245'	100	0.0	0.0	$1.9x10^{-1}$	460	medium sand and gravel
W-9	250'	100	0.0	0.0	$2.7x10^{-1}$	590	medium sand and gravel
W-9	270	100	0.0	0.0	$1.4x10^{-1}$	400	medium sand and gravel
W-9	275	100	0.0	0.0	$1.4x10^{-1}$	400	medium sand and gravel
W-9	330	100	0.0	0.0	$1.25x10^{-1}$	380	medium sand and gravel
W-9	380	100	0.0	0.0	$9.0x10^{-2}$	100	fine sand
W-9	380	100	0.0	0.0	$3.8x10^{-1}$	900	medium sand
W-2	50-55'	99	1	0.0	$2.4x10^{-1}$	570	fine to medium sand
W-2	74-75'	97	3	0.0	$1.5x10^{-1}$	410	fine to medium sand
CHANNEL SAND AND GRAVEL							
W-8	680'	91	4	5	$9.8x10^{-2}$	400	dirty gravel
W-8	690'	89	5	5	$5.0x10^{-2}$	32	dirty sand
W-2	475-502'	77	21	2	$4.7x10^{-2}$	25	dirty sand
W-2	232-252'	72	24	4	$1.4x10^{-2}$	3.5	dirty sand
SAND AND SILT ASSOCIATED WITH THE UPPER GLACIAL UNIT (AFTER SINGER, 1974)							
	6	62	38	0.0	$2.5x10^{-2}$	12.0	sand
	40	17	83	0.0	$1.8x10^{-2}$	6.0	silt
	41	23	77	0.0	$1.9x10^{-2}$	7.0	silt
	61	40	60	0.0	$2.8x10^{-2}$	15.0	silt
	63	9	83	8.0	$1.3x10^{-2}$	4.0	silt
	75	51	49	0.0	$1.9x10^{-2}$	7.0	silt-sand
CLARKE SAND (AFTER SINGER, 1974)							
	14	75	25	0.0	$4.5x10^{-2}$	39.0	sand
	15	82	18	0.0	$5.2x10^{-2}$	53	sand
	18	84	16	0.0	$5.0x10^{-2}$	49	sand
	20	87	13	0.0	$6.5x10^{-2}$	82	sand
	22	88	12	0.0	$6.3x10^{-2}$	77	sand
	24	72	38	0.0	$3.8x10^{-2}$	28	sand
	34	95	5	0.0	$8.0x10^{-2}$	124	sand
	34-A	84	16	0.0	$5.5x10^{-2}$	59	sand
	85	84	16	0.0	$5.5x10^{-2}$	59	sand
	93	84	16	0.0	$5.0x10^{-2}$	49	sand

The hydraulic potential (Φ) divided by the constant (g) equals the hydraulic head (ϕ) or level to which the ground water will rise in a well or piezometer. Ground-water movement is from points of high hydraulic head to points of lower head.

The drainage basin can be described as a three-dimensional system in which the ground water is continually moving. The direction of movement at any point within this system is dependent on the distribution of hydraulic potential.

The concept of the existence of different flow systems within a drainage basin has been well-documented by analytical and digital methods (Toth, 1962, 1963; Freeze, 1969; Freeze and Witherspoon, 1966, 1967, 1968). These studies allow for an understanding of ground-water movement within the BSW drainage basin and provide considerable information on analytical techniques which may be applied to the interpretation of hydrogeologic conditions within this basin.

Water-Level Measurements

An interpretation of the pattern of ground-water flow within the system, namely the horizontal and vertical vector components, is accomplished by the systematic measurement of water levels in established observation wells in the basin. Supportive data were obtained from chemical analyses of water samples taken at different points in the basin.

The MOE has established and maintains a total of 19 observation wells in the BSW drainage basin. Several of these wells consist of two or more piezometers in which the vertical component of flow may be determined by examining variations in the measured hydraulic heads. Additional water-level data were collected from the well records kept on file with the MOE.

Horizontal Flow Vector

A water-level contour map was prepared on which the water-level measurements for different domestic wells in the basin are shown (Map 6). The water-level contours represent lines of equal hydraulic head; ground-water flow is perpendicular to these contours. Because the water-level measurements were taken at different times of the year and the wells are finished at different depths, the data thus generated can only be used to give a rough approximation of the horizontal flow vector. The generalized horizontal direction of ground-water movement is down the regional slope from the Oak Ridges Moraine area, southward towards Lake Ontario. The water-level contour map is a subdued replica of the topographic surface map suggesting that topography is the main controlling factor on the shape of the flow system.

Vertical Flow Vector

The vertical direction of ground-water movement and the magnitude of the hydraulic gradient for a specific location can be established by measuring the hydraulic head in two or more piezometers which are placed side by side and set at different depths. In recharge areas the measured hydraulic head decreases as the piezometer depth increases. In discharge areas, the reverse holds true. Hydrographs for piezometer nests located

in different physiographic regions in the basin are presented in Figure 8. Well records for these nests are presented in Appendix B, and their locations are illustrated in Map 2.

Piezometer nest (W-8) situated in the Oak Ridges Moraine has three piezometers; one set at 240 feet, another at 398 feet and a third at 708 feet. Based on the measurements for 1972, ground-water movement is vertically downward. The permeable overburden and deep water table encountered in the installation of this nest are characteristic of conditions encountered in the Oak Ridges Moraine. This suggests that, with the exception of local discharge areas in the vicinity of streams, the Oak Ridges Moraine acts as a recharge area for the flow systems within the basin.

Piezometer nest W-5a which is located along the sharp topographic break of the South Slope has three piezometers set at 25, 49 and 151 feet. All of the piezometers are set in till of low permeability; therefore, confined ground-water conditions may be expected. The difference between the measured water levels of the two shallow piezometers indicates downward movement for the greater portion of the year. The deep piezometer flows continuously. The magnitude of the hydraulic gradient between the shallow and deep piezometers suggests that there is probably some upward leakage through the till, perhaps accounting for the reversal in flow direction noted at certain times of the year (i.e. May and June). It would appear there are at least two flow systems present in this area, a shallow (local) system and a deeper (intermediate or regional) system. Other deep wells completed along the topographic break of the South Slope display similar upward gradients in ground-water movement. These wells often exhibit flowing artesian conditions and appear to coincide with the pinchout of lenses of sand and gravel of the Oak Ridges Moraine. The tills of the South Slope act as aquitards confining the outwash sediments.

The two piezometer nests (S-4 and B-4) are finished in the Lake Iroquois Plain. Piezometer nest S-4 has three piezometers set at 49, 129 and 159 feet while B-4 has two piezometers set at 25 feet and 116 feet. Piezometer nest S-4 is situated in the coarse glaciolacustrine sediments of the abandoned Lake Iroquois shoreline. There was little fluctuation in the head measurements in the piezometers over the 1972 water year, which is in part explained by the infrequent water-level measurements (once a month). This nest exhibits a recharge configuration (downward movement). The high and low water levels of these three piezometers show reasonable correlation suggestive of hydraulic continuity between the different glacial units in which they are set.

Piezometer nest B-4 is situated in the finer-grained sediments of the Lake Iroquois Plain. The shallower piezometer is set against silty to sandy till while the deeper piezometer is in limestone. The ground water encountered in this nest, on the basis of the measured hydraulic heads, is under confined conditions and shows a recharge configuration.

Long-Term Water-Level Fluctuations

Water-level fluctuations or the changes in hydraulic head over time, are indicative of changes in pressure on the ground water in storage in the area under study. These fluctuations may result from either or both: 1) short-duration phenomena such as changes in the atmospheric pressure in the aquifer, 2) long-term phenomena such as

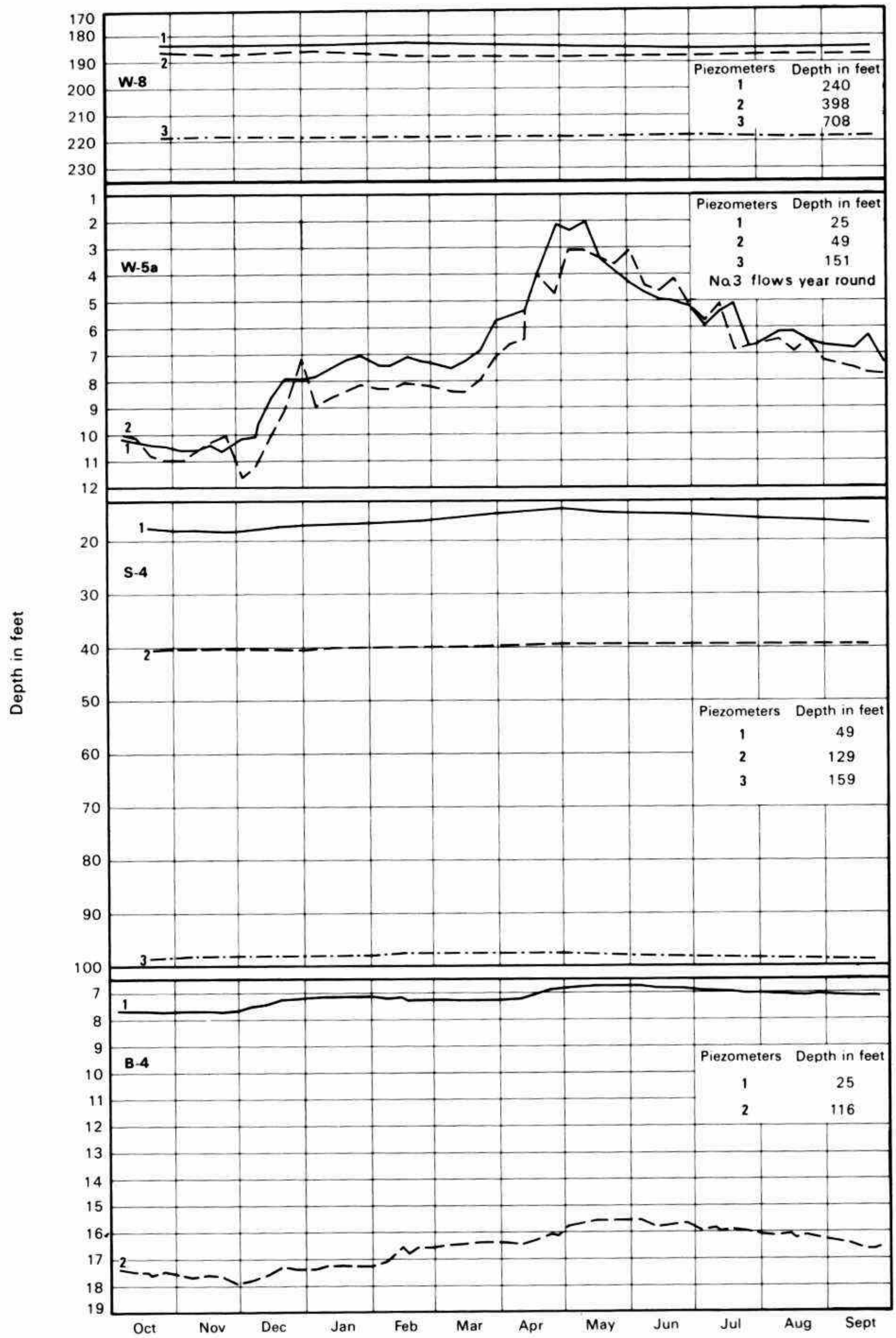


Figure 8. Water-level hydrographs for piezometer nests W-8, W-5a, S-4, and B-4 for 1972.

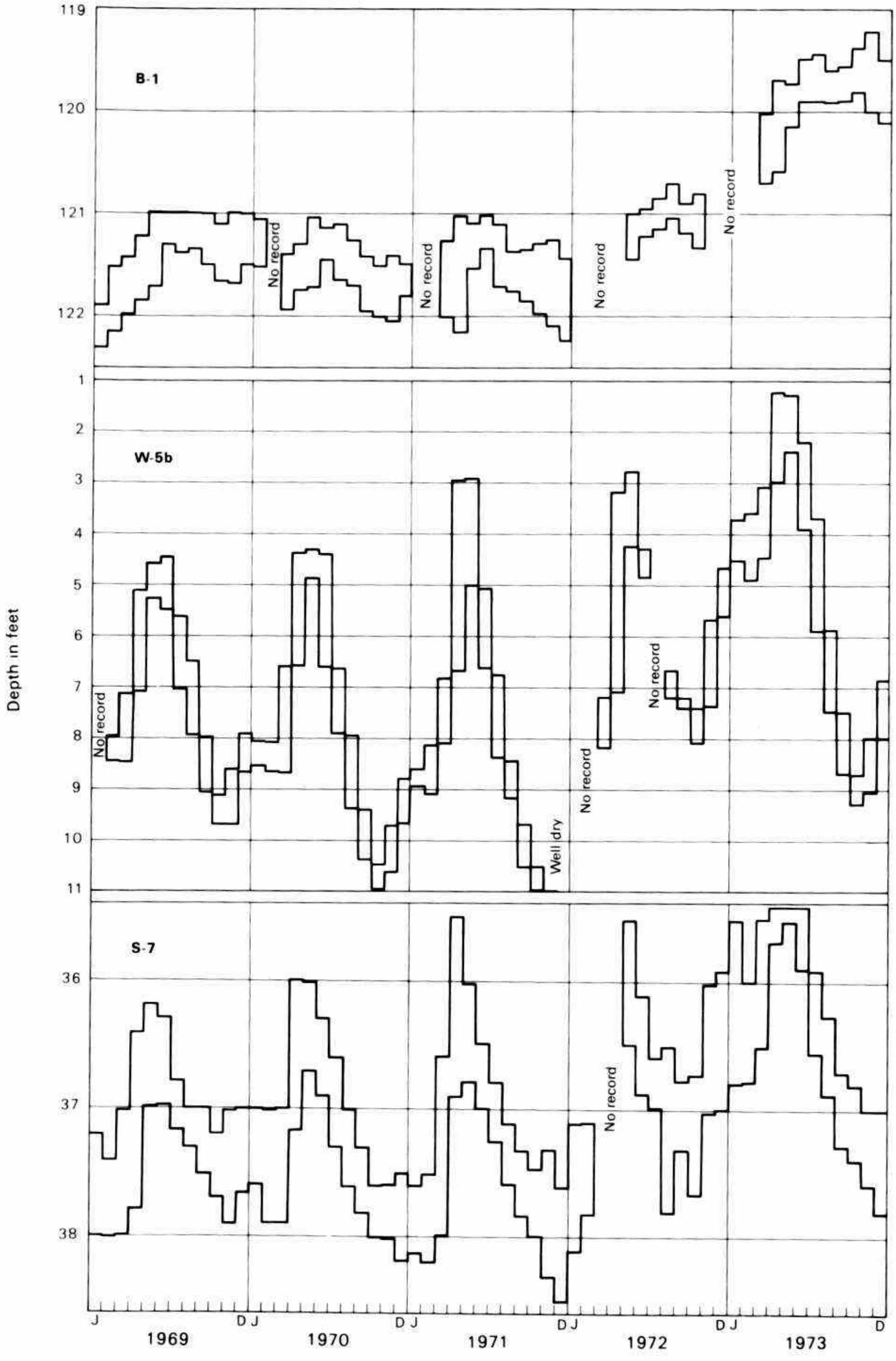


Figure 9. Water-level records for observation wells B-1, W-5b and S-7 for the interval 1969-73.

TABLE 14. CHANGE IN WATER LEVELS FOR OBSERVATION WELLS OVER THE PERIOD OF RECORD

Observation Well No.	Physiographic Region	Well Depth(ft)	Water Level Measurement (feet) on October 1 of year									Change in Water Level Over Period of Record (feet)
			1966	1967	1968	1969	1970	1971	1972	1973	1974	
B-1	Oak Ridges	187-191	124.71	124.08	121.96	121.20	121.76	121.57	120.90	119.78	119.12	+5.59 (1966-1974)
S-1B	Oak Ridges	162		148.42	145.92	144.48	145.72	145.94	145.56	144.93		+3.49 (1967-1973)
W-9	Oak Ridges	386			182.79	181.16	184.20	183.10	183.50	182.41		+0.38 (1968-1973)
W-1	Oak Ridges	117	66.68	65.99	64.99	64.76	64.97	65.06	64.83	64.39		+2.29 (1966-1973)
W-2	Oak Ridges	504	33.50	29.38	28.63	27.55	27.24	27.68	27.71	27.51		+5.99 (1966-1973)
B-2	South Slope	17		11.28	*	11.18	11.00	10.95	11.20	11.20		+0.08 (1967-1973)
W-5B	South Slope	47	12.02	9.40	10.48	9.11	10.46	10.50	7.83	8.70	7.44	+4.58 (1966-1974)
B-4	Lake Plain	28		7.20	11.34	7.63	8.51	7.66	7.22			-0.02 (1967-1973)
		120		16.78	17.10	17.01	17.46	17.35	16.59			+0.19 (1967-1973)
S-7	Lake Plain	45	38.30	37.48	37.36	37.35	37.70	37.60	37.13	37.14		+1.16 (1966-1973)
W-3	Lake Plain	154-156	42.11	41.29	41.19	41.02	41.19	40.53	40.17			+1.94 (1966-1972)
W-7	Lake Plain	24	12.72	12.35	12.45	12.50	12.41	*	12.00	12.39	12.02	+0.70 (1966-1974)
S-6A	Lake Plain	32	12.68	11.39	12.94	12.57	12.84	*	11.59	12.89		-0.21 (1966-1973)

*Incomplete Record

changes in the volume of ground water in storage due to differences between the recharge and discharge of water from the aquifer.

In the drainage basin, an examination of the water levels in the observation wells indicates that there is a seasonal pattern of fluctuation, with a rise in water levels during late winter and spring and a decline during the summer and fall. The seasonal pattern of fluctuations for three selected MOE observation wells in the basin, B-1 (Oak Ridges), W-5B (South Slope) and S-7 (Lake Plain) are illustrated in Figure 9. The range of monthly fluctuations (minimum to maximum levels) are presented by the closed bars. These fluctuations represent well-defined seasonal cycles, recharge during periods of low evaportranspiration such as the winter and spring months and little or no recharge during periods of high evapotranspiration such as the summer. The water-level drops in wells in the basin during summer months is aggravated by pumpage of water from the aquifers.

The long-term water-level fluctuations (from 1966-1974) recorded for different MOE observation wells are presented in Table 14. These measurements cover the period of record for each well up to October 1, 1974. The water levels presented in Table 14 are the daily mean levels recorded on October 1 of each year. Based on these records, there is a gain in the amount of water in storage in the basin over the period. This gain is most noticeable in the Oak Ridges Moraine where a water-level rise of 5.6 feet occurred in observation well B-1. The increase in the South Slope and the Lake Plain areas is approximately one foot. The major increases in the water levels correspond to years of high precipitation where recharge exceeds discharge.

HYDROLOGIC BUDGET

A hydrologic budget for a drainage basin represents a quantitative statement of the balance between recharge and discharge for a set interval of time. Recharge can be defined as all water entering the drainage basin. This can take the form of rain, snow, dew and subsurface underflow into the basin. Discharge is defined as all water leaving the basin. This occurs through evapotranspiration, surface and ground-water runoff in stream channels and subsurface underflow out of the basin.

The hydrologic budget can be expressed mathematically by the following equation:

$$P = Rg + Rs + Et \pm V \pm S$$

where:

P = total precipitation (rain, snow and dew),
Rg = ground-water runoff or baseflow,
Rs = surface runoff,

$$Rg + Rs = Rt$$

Rt = total stream runoff,
Et = evapotranspiration,
V = subsurface underflow both into and out of the basin,
S = change in water in storage,

$$S = S_s + S_{sm} + S_g$$

S_s = surface storage (ponds, swamps, depressions),

S_{sm} = soil moisture,

S_g = ground-water storage as reflected by ground-water levels.

This equation may be solved by the direct measurement and/or estimation of the various parameters which affect its calculation. Precipitation and the total stream runoff are measured directly; the surface runoff and baseflow components of the stream hydrograph and the evapotranspiration are estimated.

The hydrologic budget equation was applied to a period of study spanning from four to seven years (varies with the period of record of each sub-basin) for different sub-basins under examination. The physical characteristics of the sub-basins along with streamflow gauging station number and location are presented in Table 15. Over this interval, it can be assumed that the average annual change in surface water, ground water and soil moisture storage would be negligible. Similarly, with the exception of two sub-basins, the subsurface underflow into and out of the sub-basins may be eliminated because it will not measurably affect the hydrologic budget.

A "change in storage" value is included in Table 16 in order to balance the equation. This value is not a true indicator of S or the change in water in storage, but rather reflects the cumulative errors inherent in the estimation and measurement of the components of the equations.

It is therefore possible to simplify the equation to:

$$P = Rg + Rs + Et \pm S$$

Precipitation

The BSW drainage basin is primarily recharged by precipitation in the form of rain and snow. These are volumetrically measured by the various meteorological stations in the basin. The climatological data for three stations have been incorporated into this study. These stations include the federally funded station at Orono, and the MOE stations at Bowmanville-Mostert and Tyrone. Mean monthly temperature data and total monthly precipitation data for the individual stations are presented in Appendix A. The mean annual precipitation at Tyrone for the interval 1967-68 and 1973-74 was 35.75 inches, for Orono for the same interval it was 33.40 inches and for Bowmanville 30.93 inches. The mean temperature at Tyrone for the same interval was 43.3°F while for both Orono and Bowmanville stations it was 43.6°F. There was approximately a four-inch difference in the average yearly precipitation for the southern-most and northern-most stations while the difference in temperature was 0.3°F. This was attributed to the orographic effects of the Oak Ridges Moraine.

Stream Runoff

Streamflow, as measured at different hydrometric gauging stations in the drainage basin, is made up of surface and ground-water runoff. Ground-water runoff is that portion of precipitation which infiltrates through the soil to the water table and is later discharged as seepages or percolates directly into the stream channel. Surface runoff is that portion of precipitation which flows overland to the stream channel

TABLE 15. PHYSICAL CHARACTERISTICS OF THE SUB-BASINS AND THE STREAMFLOW GAUGING STATION NUMBERS AND LOCATIONS

Sub-Basin	Physiographic Region	Basin Area sq. miles	Stream Length miles	Stream Grade feet/foot	Streamflow Gauging Stn. Number	Location of Station
B-1	Oak Ridges	2.00	1.72	0.0219	02HD211	Enfield
W-1	Oak Ridges	4.61	1.54	0.0119	02HD231	Leskard
S-1	Oak Ridges & South Slope	1.81	2.04	0.0339	02HD221	Tyrone
S-2	Oak Ridges & South Slope	6.11	6.12	0.0222	02HD222	Stephen's Gulch
B-4	Oak Ridges & South Slope	10.06	5.78	0.0147	02HD214	Hampton
S-4	Lake Plain	5.38	4.42	0.0099	02HD224	Bowmanville
W-3	South Slope Lake Plain	8.04	6.36	0.0049	02HD233	Orono

TABLE 16. HYDROLOGIC BUDGETS FOR THE VARIOUS SUB-BASINS WITHIN THE BSW DRAINAGE BASIN

Sub-basin	Period of Record	Precipitation		Mean Daily Flows				Baseflow/ Total x 100%	Evapotranspiration (Et)		Change in Storage inches
		Stn. Used	ppt (P) inches	Total (Rt) cfs	Total (Rt) inches	Baseflow (Rs) cfs	Baseflow (Rs) inches		Munson-Index inches	Indirect inches	
B-1	67-74	Tyrone	35.75	1.5	10.09	0.86	5.85	60.3	22.80	25.66	2.86
W-1	67-72	Tyrone	34.45	4.2	12.32	3.68	10.86	88.2	22.67	22.09	-0.58
S-1	68-72	Tyrone	36.33	2.1	15.54	1.45	10.88	70.1	22.88	20.79	-2.09
S-2	67-72	Tyrone	34.45	7.3	16.22	3.97	8.82	54.9	22.67	18.23	-4.42
B-4	67-73	Tyrone	36.33	14.7	18.04	9.10	11.22	62.5	22.88	18.29	-4.59
S-4	66-72	Bowman-ville	30.25	4.7	11.93	1.01	2.56	21.7	21.90	18.47	-3.43
W-3	67-72	Orono	32.79	6.2	10.47	1.70	2.90	28.1	22.17	22.31	0.14

without infiltration. For purposes of this study, interflow (precipitation which infiltrates the ground but discharges to the stream prior to reaching the water table) is considered as part of surface runoff. Surface runoff generally reaches the stream channel within a few days following the storm event. After this interval, the surface runoff component of streamflow approaches zero and streamflow is derived almost entirely from ground-water runoff (Schicht and Walton, 1961).

The ground-water runoff component or baseflow was estimated from the hydrometric records by the method attributed to Wundt by Meyboom (1967). This method assumes that the monthly minimum streamflow (MNq) is taken as a measure of the ground-water runoff. The annual ground-water runoff component is therefore the total mean monthly minimum flows (1/12 ΣMNq). The ground-water runoff or baseflow values for the different sub-basins are presented in Table 16 in both cfs and inches of precipitation per square mile. They range from 21.7% to 88.2% of the total streamflow depending on the location of the gauging stations.

This method provides a means of applying a statistical rather than an arbitrary approach towards baseflow analysis. Based on previous MOE studies (U. Sibul, personal communications), the results of this method compare favourably with those from other methods, for example Langbein (1940) and Meyboom (1961).

Evapotranspiration

Evapotranspiration is defined as the discharge of water to the atmosphere by evaporation from the surface of the basin and by transpiration from plants. The sources of the water are soil moisture, the ground-water table, surface water and interception surfaces such as the leaves of plants. The rate of evapotranspiration is strongly dependent on meteorological factors, the available soil moisture, and the type of soil and vegetation cover. Evapotranspiration is almost negligible in winter but during the summer can often exceed precipitation, thus causing soil-moisture deficiencies. The combined water requirement of evapotranspiration and soil moisture during summer months has the potential for completely eliminating all infiltration to the ground-water table by exceeding basin recharge from precipitation. This is particularly evident in the decline of ground-water levels and reduced streamflows during summer months.

Evapotranspiration values were estimated by two separate methods, the Munson-Index method and the Indirect method.

In the Munson-Index method, the potential evapotranspiration is taken directly from a series of tables on which monthly mean temperatures are presented. This method assumes that there is no evapotranspiration below a monthly mean temperature of 28.4°F. The results are presented in Table 16.

The Indirect method consists of solving the simplified water balance equation:

$$Et = P - R_t$$

These results are also presented in Table 16.

A comparison of the results of these two methods with the results of more comprehensive methods (Thornthwaite method, Holmes and Robertson Moisture budget technique) indicates that these compare favourably (Table 17).

TABLE 17. ESTIMATED LONG-TERM (1967-72) EVAPOTRANSPIRATION AT ORONO AS BASED ON DIFFERENT METHODS

Method	Study	Long-Term Evapotranspiration (inches)
Thornthwaite	Singer (1974)	22.32
Holmes and Robertson Moisture Budget Technique	Singer (1974)	19.75
Munson Index	This Study	22.17
Indirect method Station W-3	This Study	22.31

Application of the Simplified Hydrologic Budget Equation to the Sub-basins

The various components of the simplified hydrologic budget equations as applied to the sub-basins within the BSW drainage basin are presented in Table 16. The location of these sub-basins is presented in Map 2.

Sub-basin B-1 and W-1 - These two sub-basins lie fully within the Oak Ridges Moraine physiographic region. Meteorological data used in the hydrologic budget for the sub-basins were obtained from the meteorological station at Tyrone. From 1967 to 1974, annual precipitation averaged about 35 inches, whereas the amount lost through evapotranspiration as calculated by the Munson Index method averaged 22.7 inches. This value may be overly high as it does not take into account either the permeable overburden which would allow for rapid infiltration nor the deep-lying water table which would reduce the potential amount that could be lost through evapotranspiration.

The total mean daily discharge recorded at B-1 and W-1 is 10.1 and 12.3 inches/square mile, respectively. The estimated baseflow component for these stations is 5.8 and 10.9 inches/square mile (60.3% and 88.2% of the total flow), respectively. The high percentage of baseflow to streamflow is characteristic of areas in which most of the precipitation infiltrates and later discharges to the streams as ground water.

The measured piezometric surfaces during the period of record show a gain of almost five feet in sub-basin B-1 and 1.3 feet in sub-basin W-1. If it is assumed that this gain can be equated to a similar gain in the water table, and if an empirical value of 0.2 is assigned to the specific yield of the overburden (based on specific yield values for similar materials), the amount of water taken into storage would be equal to approximately 2 inches of precipitation per year for the seven years of record in B-1 and 0.7 inches per year in W-1 for five years of record.

A rough estimate of the potential volume of water which could leave these two sub-basins by underflow can be obtained by solving the following equation:

$$Q=TIL$$

where:

Q = underflow in gallons per day (Igpd) converted to cfs/sq. mile

T = average coefficient of transmissibility (Igpd/ft) estimated to be about 5000 Igpd/ft based on pump test data,

I = hydraulic gradient (ft/mile) estimated to be about 80 ft/mile,

L = width of the cross-section through which flow is occurring (miles). Arbitrary value of ¼ mile is assigned as the approximate width of both drainage channels near the stream gauging stations.

The calculated volume of water which could potentially leave the sub-basins by underflow is 0.09 cfs/sq. mile for B-1 and 0.04 cfs/sq. mile for W-1 or 0.81 inches/sq. mile and 0.52 inches/sq. mile, respectively.

Sub-basins S-1, S-2 and B-4 .... These three sub-basins overlap both the Oak Ridges Moraine and the South Slope physiographic regions. The meteorological station at Tyrone was used to provide the temperature and precipitation data. From 1967 to 1973 the precipitation averaged 36.33 inches. The potential evapotranspiration as calculated by the Munson Index method averaged 22.8 inches. As for sub-basins B-1 and W-1, the calculated evapotranspiration is assumed to be higher than the actual.

The total mean daily streamflows for these three stations are appreciably higher than those flows in the other physiographic regions (Table 16). The percentage of baseflow to streamflow is 54.9% for sub-basin S-2, 62.5% for sub-basin B-4 and 70.1% for sub-basin S-1. These percentages are slightly lower than those obtained for the Oak Ridges Moraine which is to be expected because of lower overburden permeabilities (till) of the South Slope and subsequent lower infiltration.

There has been a small increase (approximately 1 to 2 feet) in the amount of water in storage in these sub-basins as is indicated in the rise in water levels in the local observation wells. A reliable estimate of the effective volume taken into storage cannot be made, however, because the ground water in these wells is under confined conditions. Underflow is assumed to be negligible in this area.

Sub-basins S-4 and W-3 .... Sub-basin S-4 lies entirely in the Lake Plain physiographic region while sub-basin W-3 lies partially in the Lake Plain and partially in the South Slope physiographic regions. The average annual precipitation measured at the Bowmanville station (S-4) for the 1966-72 period of record is 30.25 inches, while that for the Orono (W-3) for the 1967-72 period is 32.79 inches. The Munson evapotranspiration for the two sub-basins, as expressed in inches of precipitation, is 21.9 and 22.2, respectively.

The percentage of baseflow to total streamflow is 21.7% for S-4 and 28.1% for W-3 (Table 16). These values reflect the lower permeability of the overburden in this area and a reduction in the amount of precipitation which infiltrates.

From the observation-well data recorded for sub-basins S-4 and W-3, there has been an increase in the water levels from 1966-1972 of approximately 1.6 feet. If a specific yield of 0.1 (10%) is assigned to the overburden, the amount of water taken into storage is approximately equal to 0.3 inches of precipitation per year for the 1966-72 period of record.

No estimate of the underflow was made; however, it is assumed to be negligible in these sub-basins.

POTENTIAL QUANTITY OF GROUND WATER AVAILABLE FOR USE

A rough estimate of the potential quantity of ground water available for use in different areas can be obtained from the hydrologic budgets of the sub-basins. This study shows that most of the ground-water discharges from these sub-basins as baseflow and therefore the potential quantity of water obtainable from an area can be equated to the long-term mean baseflows. The permeable overburden in the northern portion of the study area allows for the rapid infiltration of precipitation, thus only a small part of streamflow is a result of surface runoff. Based on estimates of baseflow, the long-term mean discharge for the sub-basins W-1, S-1, S-2 and B-4 ranges from approximately 8.9 to 11.2 inches of water/square mile/year (129 to 162 million imperial gallons/square mile/year). Sub-basin B-1 was not included in this average because a significant amount of water is assumed to have been taken into storage and lost through underflow in this sub-basin.

The southern portion of the basin is considerably less productive. The potential quantity of water available for use in this area, as based on the baseflow estimates for sub-basins S-4 and W-3, is only about 3 inches of water/square mile/year (43 million imperial gallons/square mile/year).

Assuming that all ground-water discharge can be diverted to the cones of depression for wells finished in the different areas, this water would be available for use. The actual amount would be somewhat less and would have to be determined by more detailed studies.

Existing Water Use

Water use in the drainage basin is grouped and discussed by the principal users of the resource: (1) irrigation, (2) municipal water supply, (3) rural domestic water supply. The type of supply, surface or ground water, is dependent on the availability and chemical quality of the supply and the economic considerations inherent in extracting the supply and transporting it to where it will be used.

Ground and surface water is used extensively for irrigation and stock watering and for water-supply purposes. Favourable hydrogeologic conditions have resulted in a high rate of success in the drilling of wells and in the obtaining of satisfactory supplies of water. A total of 1059 well records were examined in this study; of these, only 19 wells were abandoned because of insufficient supplies. The majority of these abandoned wells occurred in the Lake Plain area. The failure of these wells to develop an adequate water supply is probably a result of construction difficulties (fine sand or insufficient depth) rather than a lack of water.

Existing water takings have had a negligible effect on the water levels and streamflows in the basin. As such, there has been no mining of the water resource to date.

In order to manage the amount of water used during "dry" periods when water demands are high, a water-taking permit program was established in 1961. Water takings of more than 10,000 gallons of water per day from new wells, inlets, diversions or storage works for purposes other than domestic, stock or firefighting, require a permit in the Province of Ontario (Ontario Water Resources Act, Section 37). Under

TABLE 18. BREAKDOWN OF THE PERMITTED WATER TAKINGS FOR THE BSW DRAINAGE BASIN

Sub-Basin and Purpose	No. of Permits	Amount in Imperial Gallons per Day: All Sources	Ground Water	Surface Water	Undifferentiated
Wilmot Creek					
Irrigation	2	721,500		721,500	
Water Supply	2	208,800	208,800		
Recreation	1				
Commercial	1	1,200,000			1,200,000
Sub-Total	6	2,130,300	208,800	721,500	1,200,00
Soper Creek					
Irrigation	5	1,720,200		1,264,000	456,000
Commercial	1				
Storage Retention	1				
Sub-Total	7	1,720,200	- - -	1,264,200	456,000
Bowmanville Creek					
Irrigation	5	495,700	28,800	250,200	216,700
Commercial	1	432,000			432,000
Storage Retention	4				
Sub-Total	10	927,700	28,800	250,200	648,700
TOTAL	22	4,778,200	237,600	2,235,900	2,304,700
Lake Ontario					
Commercial	1	3,888,000		3,888,000	

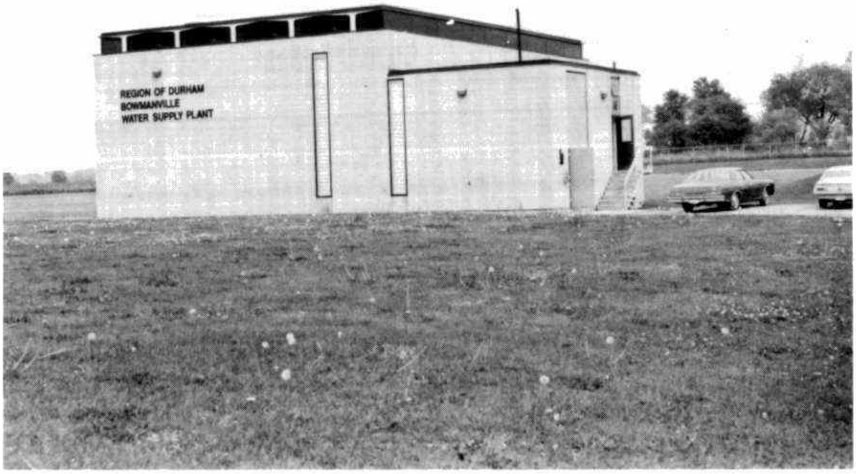


Photo 11. The water-supply plant near Bowmanville which obtains water from Lake Ontario.

the present permit program, water takings prior to the enactment of this legislation are usually exempt.

A total of 23 permits have been issued in the basin as of January 1976. A breakdown of the permitted water takings for the basin is presented in Table 18.

Irrigation .... Irrigation is practiced during summer months when it is essential to maintain soil moisture levels for the growth of crops. The major irrigated crops are canning and orchards. As based on the water-taking permits, the permitted water takings amount to approximately 2.9 million gallon per day during the summer months. A large portion of this irrigation water is lost from the basin water supply through evapotranspiration.

Municipal Water Supplies .... Three communities have municipal water-supply systems; these are Bowmanville, Newcastle and Orono. Newcastle and Orono utilize ground-water supplies exclusively while Bowmanville uses a combined ground-and surface-water supply.

Newcastle obtains its municipal water supply from two wells which are completed in the channel sand. The older of the two wells has a pump capacity of 90 Igpm and is rated between 70 to 90 Igpm or 100,800 to 129,600 Igpd. The newer well has a capacity of 50 Igpm or 72,000 Igpd but because of high nitrates is only used for standby purposes. The performance tests and well logs are presented in the section on pumping and recovery tests in Appendix C. The total water use for Newcastle in 1975 was 26.0 million Imperial gallons (mIg).

Orono also obtains its water supply from two municipal wells, one rated at 75 Igpm (108,000 Igpd) and the other at 100 Igpm (144,000 Igpd). The performance tests and well logs are presented in Appendix C. The total water use for Orono in 1975 was 23.9 mIg.

Bowmanville obtains its water supply from two sources, a flowing well-natural spring supply system and Lake Ontario. The capacity of the flowing well-natural spring supply system is rated at 325,000 Igpd which gravity feeds into a 340,000 Ig equilization tank. The Lake Ontario plant (Photo 11) is rated at 2.0 Igpd capacity which feeds into an 800,000 Ig storage tank. In addition, an elevated storage tank in Bowmanville has a capacity of 340,000 Ig. The total water use for Bowmanville in 1975 was 516.4 mIg.

Rural Domestic Water Supplies .... Rural domestic water needs are met by ground water produced from water wells. Based on the well records, there were a total of 1059 drilled and bored water wells (19 abandoned) in this basin as of January 1976. Approximately 700 of these wells are situated in the area south of the abandoned Lake Iroquois shoreline. The rural domestic water demand in the basin is estimated as approximately 4000 Igpd/square mile. This estimate assumes a rate of 400 Igpd for each of the 1040 wells in use. The water demand in the southern portion of the basin where the majority of the wells are situated is in the order of 7,000 Igpd/square mile. No estimate of stock-watering use was made.

HYDROCHEMISTRY

Water quality is an important consideration in the evaluation and development of the water resources of an area. The hydrochemical characteristics of the ground and surface waters determine the suitability of these waters for commercial, municipal and domestic uses. Similarily, the areal distribution of the hydrochemical characteristics and an

understanding of the factors which contribute to the hydrochemistry of the ground and surface waters assists in confirming and establishing flow patterns in an area. The hydrochemistry of the ground and surface waters in the BSW drainage basin are discussed in the following sections.

General Hydrochemical Characteristics and Classification

The chemical composition of surface and ground waters is subject to continuous change as the waters move through the hydrogeologic domain. This change in composition, both on a local and regional scale, is a function of several interacting factors.

Some of the common controlling factors are:

1. the initial chemical composition of the water prior to contact with the ground surface,
2. the temperature of the water and the atmospheric pressure exerted on the water molecules as they infiltrate,
3. the mineralogy of the medium through or over which the water flows in relation to chemical reactivity, sorption and ion exchange mechanisms,
4. the microbiological activity in the medium, and
5. the contact time between the medium and the waters in relation to flow velocity.

When viewed on a regional scale, certain sequential patterns can be established from the hydrochemistry. For instance, ground water in a recharge zone generally has a bicarbonate character while that in a discharge zone generally has a predominant chloride character. The evolutionary sequence in chemical composition as described by Chebotarev (1955) for ground waters within a regional flow system is as follows:

$$HCO_3^- \rightarrow HCO_3^- + Cl^- \rightarrow Cl^- + HCO_3^- \rightarrow Cl^- + SO_4^= \quad \text{or}$$

$$SO_4^= + Cl^- \rightarrow Cl^-$$

Schoeller (1959) attributed changes in hydrochemistry to three types of zonations. These are:

1. geological zonation,
2. vertical zonation, and
3. zonation by climate.

Geological zonation reflects the physical and chemical characteristics of the hydrogeologic units through and over which water moves. Therefore, water samples collected from similar hydrogeologic units should have hydrochemical characteristics which are broadly similar. For example, ground water in calcite-rich sediments should generally have high calcium and bicarbonate concentrations. Waters in contact with clay, clay tills and other fine-grained materials will often be high in total dissolved solids and have $SO_4^=$ and Cl^- contents exceeding HCO_3^-. In addition, the cation exchange capacity of fine-grained materials often are higher than coarser materials, resulting in Ca^{++} - Na^+ exchanges to produce Na^+ enriched waters.

Vertical zonation is described as the relation between hydrochemistry and the position of the water sample relative to the flow system. In general, ground-water quality deteriorates with increasing distance below the ground surface because of reduced flow rates. This increases the contact time between the water and the geologic units. Well-water

samples collected in the same area from wells finished to different depths may have very different chemical character. This evolutionary progression is similar to that of Chebotarev (1955) with the composition of the ground water changing with increasing depth from bicarbonate waters to chloride waters.

Zonation by climate plays a minor role in the temperate climate regime of Ontario. Although there is some concentration of chlorides and sulphates in the soil zone due to evapotranspiration, the substantial rainfall and high infiltration characteristics of the overburden in this area dilute the chloride and sulphates in the soil zone and carry them to the ground-water table where further dilution takes place.

The application of either Chebotarev's evolutionary sequence or Schoeller's classification scheme to delineate the pattern of ground-water movement in a specific area should only be used in unison with a previous understanding of the flow system based on hydraulic principles. Individual water samples tend to reflect localized conditions which in a heterogeneous hydrogeologic environment may give anomalous values with respect to the sample's position in the flow system. Several sample values, however, are useful in reflecting regional trends in hydrochemistry and can possibly differentiate between different flow systems such as a shallow local system and a deeper-lying regional system.

Method of Investigation

A total of 154 water samples were collected in 1968 and 1971 from various domestic water wells, streams and springs in the study area. The water-well samples were collected from wells finished to different depths in the basin in order to obtain a comprehensive sampling of the ground water. These waters were analyzed at the MOE laboratory for the following ions: bicarbonate, chloride, sulphate, nitrate, calcium, magnesium, sodium, potassium and iron. The conductivity and pH of the samples were also measured. The ion concentrations expressed in milligrams per litre are listed in Appendix D. The sample site locations are illustrated in Map 7.

The ion balances, equivalents per million (milliequivalents per litre) and various ratios between different ions were calculated for each sample, in addition to means for groups of samples, by a computer program written by J. Coward (personal communications). The accuracy and completeness of the chemical analyses of the water samples were checked by the cation-anion balance for each sample.

The difference between the sum of the cations and anions in milliequivalents per litre will generally not exceed 1 or 2 percent of the total of cations and anions in waters of moderate TDS concentration (250-1,000 mg/l), if the analytical work is accurate and if all the significant ions have been analysed (Hem, 1970). An arbitrary limit of 7.5% error was set in order to compensate for the inherent inaccuracy in the reproducibility of the analytical results and for incomplete analyses where not all the significant species were analysed. Between the sampling and analysis time, certain chemical changes may take place in the water. The water sample may lose CO_2 or precipitate out minerals such as calcite or dolomite thus resulting in not completely accurate chemical analyses. Similarily, only the major cations and anions were analysed; minor ions may, in certain waters, be significant components. All sample analyses which had ion imbalances in excess of 7.5% were rejected.

It must be stressed that this does not necessarily indicate that all samples of less than 7.5% error are complete analyses but rather that it can be assumed that there are no major errors in the concentrations of the major ions.

Hydrochemistry of the Ground Water in the Basin

The analyses are arbitrarily divided into four groups, each group consists of samples collected in a different physiographic area. The four groups include ground-water samples collected in the three major physiographic regions, the Oak Ridges Moraine, the South Slope and the Lake Iroquois Plain. The South Slope is further subdivided into the areas above and below the 700-foot contour. The chemical analyses of ground-water samples collected in the basin are listed in tables 20a, 20b, 20c and 20d by the hydrochemical groupings. These analyses are presented diagramatically in Piper Trilinear plots, figures 10, 11 and 12. Statistical treatment of the data suggests that certain hydrochemical trends are evident from these groupings. The following trends are observed in the examination of the analyses:

1. There is a general increase in the concentrations (absolute values) of specific ions and in the total dissolved solids in the ground water from north to south in the basin.
2. There is a progressive change in the relative ratios (e.g. Ca/Mg, HCO_3/Cl, and SO_4/Cl) of specific ions in the ground water from north to south.

Absolute Values .... The three major anions, bicarbonate (HCO_3), sulphate (SO_4) and chloride (Cl) are examined in this study. The bicarbonate ion, as indicated by the percentage of bicarbonate with respect to the other anions, is the principal anion in the ground water in the basin. The concentration of bicarbonate in the ground water is fairly constant averaging from 74.8 to 90 percent of the total anions (Table 19). The concentration is governed by the CO_2 pressure in the atmosphere and in the soil, which over the basin would vary very little.

The sulphate and chloride concentrations in the ground water are dependent on the concentration of gypsum, alkali earths, sulphates and salts in the subsurface through which the water moves and the reaction processes involved in the dissolution of these minerals. For example, chlorides are more soluble then sulphates thus resulting in an increase in the chlorides and a general decrease in the proportion of SO_4 to Cl along the flow path. Both of these anions undergo progressive accumulation as the ground water moves through the medium and often results in lower quality waters in the lower reaches of basins.

The concentrations (absolute values) of all the anions in the ground water show an increase from north (Oak Ridges Moraine) to south (Lake Plain) as is illustrated in Table 19. The SO_4 and Cl concentration in the ground water, however, show a greater increase than that of HCO_3.

Four cations, calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) are examined in this study. In general, the cation concentrations increase in relation to the concentration of the anions as both are dependent on the dissolution of salts in the medium in which these ions are paired. Ion exchange processes also have the potential for changing the ion concentrations. This phenomenon, although present to some degree in all fine-grained sediment, is especially pronounced in

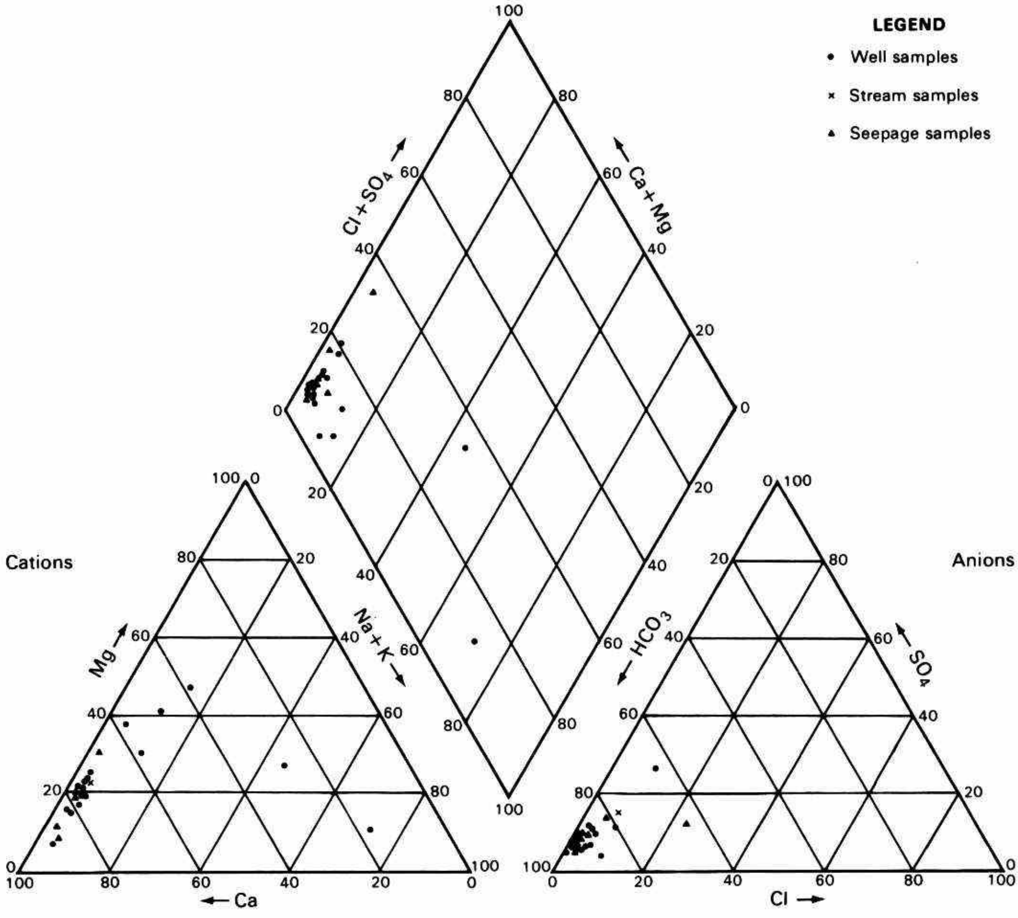


Figure 10. Major-ion hydrochemistry of water in the Oak Ridges Moraine area.

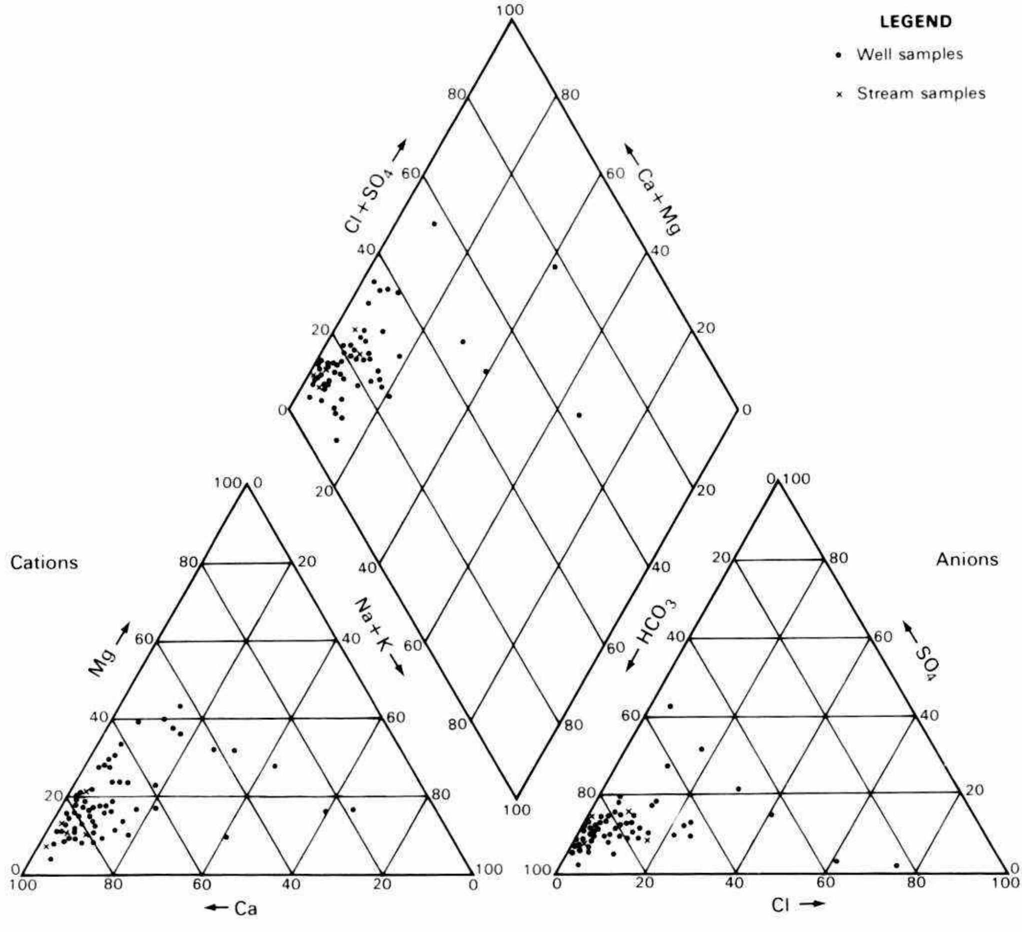


Figure 11. Major-ion hydrochemistry of water in the South Slope area.

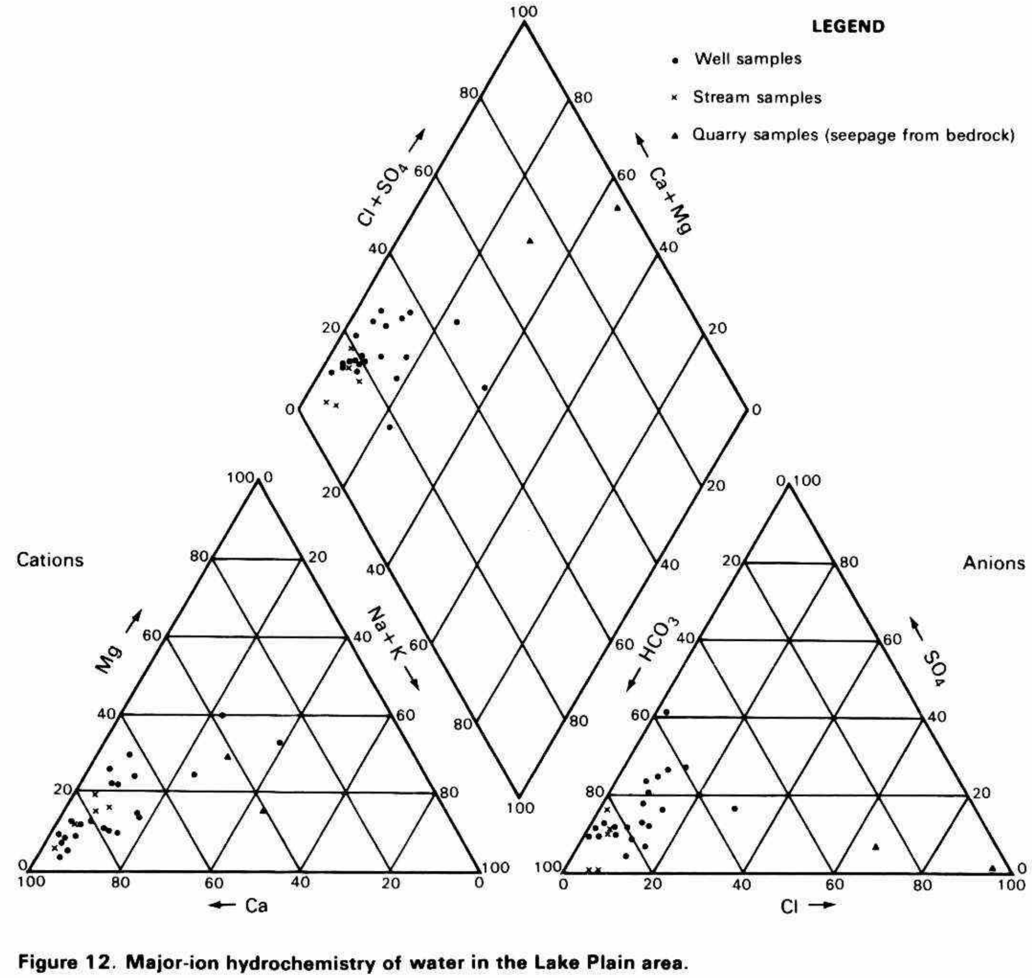


Figure 12. Major-ion hydrochemistry of water in the Lake Plain area.

TABLE 19. MEAN ABSOLUTE AND RELATIVE ION CONCENTRATIONS FOR GROUND WATER SAMPLES COLLECTED IN THE OAK RIDGES MORAINE, SOUTH SLOPE AND LAKE PLAIN PHYSIOGRAPHIC REGIONS

		ABSOLUTE VALUES														RELATIVE RATIOS						
		ANIONS						CATIONS														
	# of	Bicarbonate		Sulphate		Chloride		Calcium		Magnesium		Sodium		Potassium		Ca	Ca + Mg	HCO_3	HCO_3	SO_4	Cond.	
Location	Samples	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%	/mg	Na + K	SO_4	Cl	Cl	umhos/cm	TDS
Oak Ridges	15	178.2	90.0	14.1	7.5	2.8	2.0	56.8	70.6	11.5	23.7	4.4	5.1	0.9	0.6	4.2	22.3	13.4	70.1	4.9	370.9	305.1
South Slope	59	226.8	77.8	39.2	12.0	27.1	10.2	90.3	71.1	13.0	17.1	14.7	8.6	5.1	1.9	5.2	13.4	8.7	18.3	2.4	587.3	465.0
Lake Plain	23	264.4	74.8	56.4	14.5	34.0	10.7	110.3	73.3	15.1	15.9	16.0	8.5	9.3	2.3	7.8	13.8	7.0	12.8	2.2	713.9	562.9

*Samples which appear to have been treated by water softeners were excluded from the statistical treatment of the data.

argillaceous materials and organic substances.

The concentration of all four cations in the ground water increases from north to south as is illustrated in Table 19. There is a change in the ratio of these ions with respect to each other, however. Whereas the calcium concentration remains relatively constant averaging 70.6 to 73.3 percent of the cation concentration from north to south, the magnesium concentration decreases from 23.7 to 15.9 percent. Both the sodium and potassium concentrations increase, averaging 5.1 to 8.5 percent for sodium and 0.6 to 2.3 percent for potassium from north to south. This is borne out in the cation triangle with an increasing scatter of points towards the sodium-potassium vertex from the calcium and magnesium base line.

Relative Values .... The relative ratios used in this study include:

$$\frac{Ca}{Mg}, \quad \frac{HCO_3}{SO_4}, \quad \frac{HCO_3}{Cl}, \quad \frac{SO_4}{Cl} \text{ and } \frac{Ca + Mg}{Na + K}$$

Specific trends in the concentrations of the cations and ions can be established by the values obtained from these ratios. The relative values are presented for each analysis in tables 20a, b, c and d while the mean values for each physiographic region are presented in Table 19.

The following trends can be established from Table 19:

1. The Ca/Mg ratio increases from north to south.
2. The Ca+Mg/Na+K ratio decreases from north to south.
3. The HCO_3/SO_4, HCO_3/Cl and SO_4/Cl ratios decrease from north to south.

These trends indicate that the hydrochemistry of the ground water is evolving in a set pattern from the northern recharge areas along the flow path to the southern discharge areas. This conforms with the evolutionary sequence discussed by Chebotarev (1955) and Schoeller (1959).

Hydrochemistry of the Seepage Waters

Eleven seepage water samples were collected from ground-water discharges from the overburden in the vicinity of Wilmot Creek. These discharges occur in the South Slope Region along a sharp topographic break. The hydrochemistry of these samples is listed in Table 20e. The chemical composition of these samples is relatively uniform. The total dissolved solids content and the absolute and relative values of the samples are similar in composition to the ground water collected in the Oak Ridges. These waters are of the calcium-bicarbonate type and are lower in total dissolved solids, chloride, sulphate and sodium and potassium than the ground waters of the South Slope and Lake Plain areas. The HCO_3/SO_4, HCO_3/Cl and SO_4/Cl values are higher. It is assumed that these seepages represent discharge from shallow, local flow systems in the Oak Ridges.

Two seepage water samples were collected from ground-water discharges along bedrock fissures in the St. Mary's Quarry. The hydrochemistry of these samples is presented in Table 20e. These two samples are highly mineralized with total dissolved solids concentrations of 1681.8 and 7573.1 ppm. The bicarbonate and sulphate concentration of

these seepage waters are in the same order of magnitude as those of ground-water samples collected in the Lake Plain. The chloride, calcium, sodium, magnesium, and potassium concentrations of these two samples are considerably higher than other seepage samples. These waters are tentatively compared to those of the chloride facies described by Chebotarev (1955) and are assumed to represent discharge waters from a regional flow system.

Hydrochemistry of the Surface Waters

Fourteen water samples were collected from the streams in the basin. The hydrochemistry of these surface-water samples is presented in Table 20f.

The hydrochemistry of the surface water is dependent on the combined chemical contribution of baseflow (ground-water runoff) and overland flow (surface runoff). In general, the increase in TDS content of the surface waters in the southern portion of the basin reflects a similar increase in TDS content of the ground waters which contribute to the streamflow.

Suitability of Ground and Surface Waters for Use

The chemical quality of ground and surface water is an important consideration in evaluating its suitability for use as a water supply. In order to develop usable criteria for water quality, standards have been established by the MOE and other governmental agencies based on specific uses. These standards are presented and discussed in the MOE booklet entitled "Guidelines and Criteria for Water Quality Management in Ontario" (1974). The published criteria are listed under permissible and desirable concentrations. Waters which exceed the permissible concentration criteria should not be used for supply purposes. Good quality waters are those which meet the desirable concentration criteria. The permissible and desirable concentration criteria for public water supplies for some of the major chemical constituents are presented below:

Chemical Constituents	Permissible Criteria (mg./l.)	Desirable Criteria (mg./l.)
Chloride	250	<25
Sulphate	250	<50
Total Dissolved Solids	500	<200
Hardness	Acceptable levels will vary with local hydrogeologic conditions and consumer acceptance.	
Nitrate as N	10	Virtually absent
Iron (filterable)	0.3	Virtually absent
pH (range)	6.0-8.5 units	Least amount of interference with treatment process.
Pollution Indicator Organisms	Coliform and other pollution organisms should be virtually absent from all supplies.	

The microbiological content of the water supply should be established prior to use by submitting a sample of the water to the local Ministry of Health representative for examination. Nuisance organisms should be virtually absent from water supplies. Where they occur it will be necessary to disinfect the water supply.

The suitability of the water for irrigation should be established through the local agricultural representative. Presented below is a sample list of quality criteria for agricultural usage (irrigation). The relative tolerance of crop plants to different chemical constituents in the water varies considerably and should be established prior to the initiation of irrigation.

Chemical Constituents	Recommended Maximum Limit of Concentration (mg/litre)
Chloride	150
Chloride (special requirement for tobacco)	70
pH range	4.8-9.0 units
Total dissolved solids (TDS)	500
Sodium adsorption ratio (SAR)	6

The Sodium Adsorption Ration (SAR) is an indirect expression of the tendency of irrigation waters to enter into base exchange reactions in the soil. The SAR values are expressed mathematically as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where ion concentrations are expressed in milliquivalents per litre.

Milligrams per litre values are converted to milliequivalents per litre by multiplying the mg/l value by the reciprocal of the formula weight of the ion divided by its ionic charge. Individual SAR values for the water samples collected are included in tables 20a, b, c, d. Comments on the salinity and sodium hazards based on soil types, drainage, and salinity tolerances of irrigated crops are included in the diagram of the sodium adsorption ratio and electrical conductivity, illustrated in Figure 13. With certain localized exceptions, the majority of the water samples collected in the basin lie within the recommended quality criteria standards for municipal, domestic and agricultural uses.

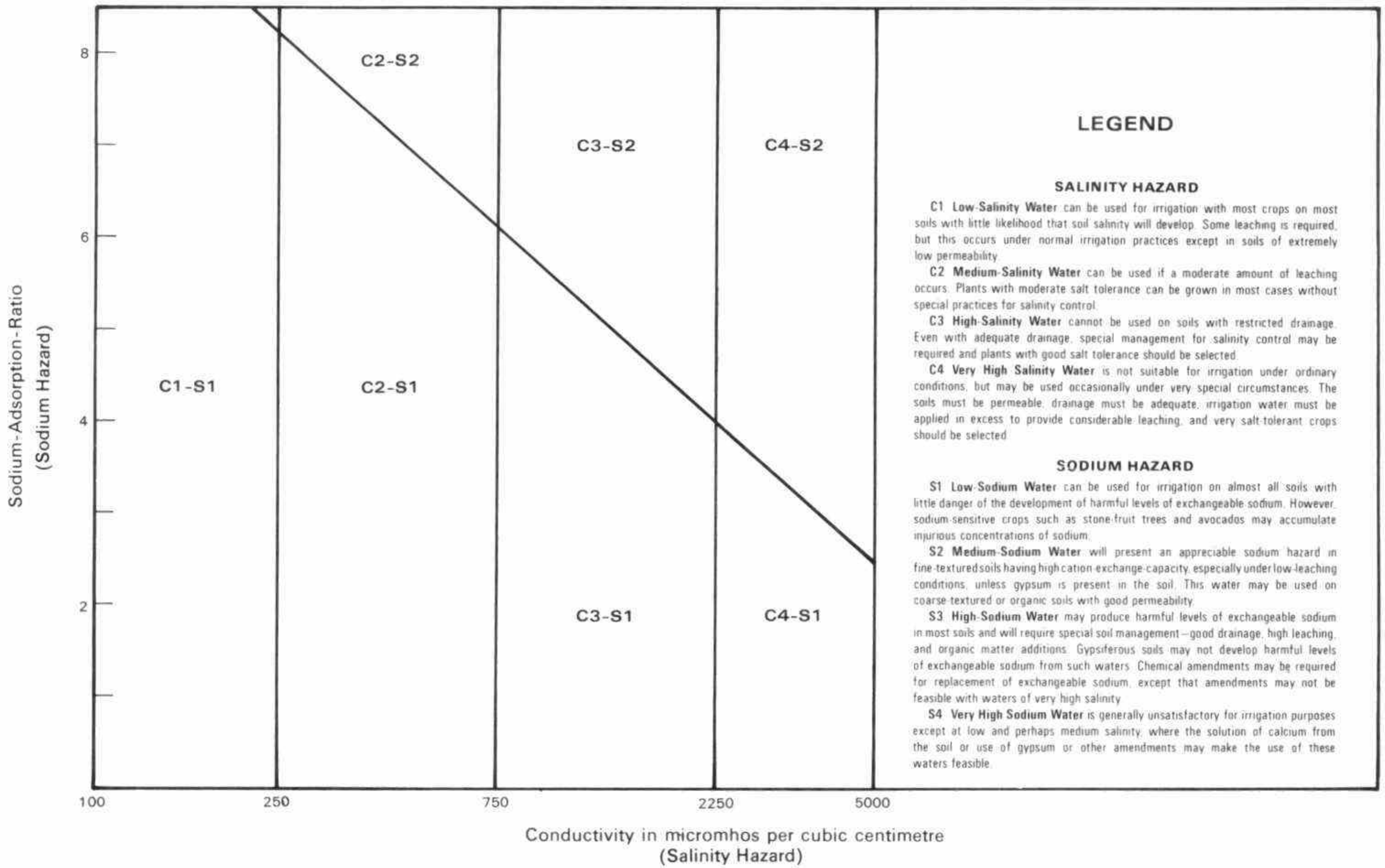


Figure 13. Suitability of water for irrigation, classified on the basis of sodium and salinity hazards (diagram and legend after U.S. Salinity Laboratory Staff, 1954).

SUMMARY

The Bowmanville, Soper and Wilmot creeks drainage basin was one of a series of representative basins studied by the Ontario Ministry of the Environment as its contribution to the International Hydrological Decade (IHD) Representative Basin Program. This investigation presents the findings obtained from an inventory of the water-well records for the area, the installation of observation wells, streamflow gauging and meteorological stations, surficial mapping, and water sampling for inorganic chemical quality. The fundamental objective of this study is to evaluate the ground-water resources of the basin in terms of their hydrogeologic setting, quality and useability.

The drainage basin is superimposed on three major physiographic regions: the Oak Ridges Moraine, the South Slope and the Lake Iroquois Plain. The Oak Ridges forms the height of land in the northern section of the basin dividing the drainage south into Lake Ontario and north into Lake Scugog. The surface is broken with a hilly, knob and kettle topography. The South Slope, the southern slope of the Oak Ridges Moraine, is a rolling till plain. The Lake Plain is an area of low relief inundated during the Pleistocene by the waters of Lake Iroquois. The northern limit of the Lake Plain follows a well-developed, abandoned shoreline.

The basin is drained by three main creeks: the Bowmanville, Soper and Wilmot creeks. These creeks have their origin in the Oak Ridges Moraine where they flow southward towards Lake Ontario. The respective drainage areas are 33.39 mi.^{2}, 29.86 mi.^{2} and 31.89 mi.^{2}.

Climate is influenced by the moderating effects of Lake Ontario. The mean annual precipitation (1967-1973) for the nine stations in the basin is 33.3 inches. The mean annual temperature (1968-1973) at the Bowmanville-Mostert station is 44.4^{o}F, and at the Orono station is 43.7^{o}F.

The bedrock underlying the basin is of Ordovician age and consists of two units, the Lindsay Formation and the Whitby Formation (Map 3). The Lindsay Formation is a grey to greenish-grey, fine-grained argillaceous limestone unit in beds of from one inch to two feet in thickness. The Whitby Formation is a black, calcareous shale unit with interbedded limestone beds. The bedrock surface is irregular with a local relief generally on the order of 30-70 feet. There are strong similarities between the existing surface topography and that of the bedrock surface.

The surficial deposits consist of sediments of Pleistocene and Recent age. Glaciolacustrine deposits south of the abandoned Lake Iroquois shoreline range from sand and gravel of a nearshore and deltaic nature to offshore sediments such as varved silt and clay. Exposures of till occur on drumlins in this area. North of the Lake Iroquois shoreline, the overburden thickens appreciably to make up the rise of land known as the Oak Ridges Moraine. The overburden on the south slope of the Oak Ridges Moraine and of the moraine itself consist of a variety of glaciofluvial, glacial and Recent deposits. These include sand and gravel in outwash, kame and dune deposits and sandy to silty till in ground moraine. The following stratigraphic sequence is tentatively proposed for the basin area north of the Lake Ontario shorebluffs:

	Epoch, Stage and Substage	Stratigraphic Unit	Lithology and Origin
	Recent Stage	Recent Sediments	Swamp, bog, alluvium and aeolian sediments (gravel, sand, silt, clay, muck)
PLEISTOCENE EPOCH/WISCONSINAN STAGE	Late Substage	Lake Iroquois Deposits	Beach, near and offshore sediments (gravel, sand, silt and clay)
		Upper Drift Unit	Glacial and glaciofluvial sediments (till, gravel, sand and silt)
	Middle Substage	Middle Drift Unit	Glacial, glaciofluvial and glaciolacustrine sediments (till, gravel, sand, silt and clay)
	Early Substage	Lower Drift Unit	Glacial, minor glacio-fluvial sediments, (till, gravel, sand, silt and clay)

The time correlations are relative, being based on similarities in stratigraphic sequence with units in the Scarborough, Duffins Creek-Rouge River drainage basin and Lake Ontario bluffs areas. Each unit represents an interval of deposition during the Wisconsinan and Recent Stages.

The hydrogeologic units which constitute the major aquifers in the drainage basin include:

1. channel sand and gravel situated in bedrock lows and ancestral drainage channels (possibly Lower Drift Unit),
2. glaciofluvial and glaciolacustrine sand and gravel of the Middle Drift Unit,
3. glaciofluvial sand and gravel of the Upper Drift Unit, and
4. abandoned Lake Iroquois beach and nearshore deposits.

The bedrock and tills, although water-bearing and locally productive, are not considered to contribute significantly to the water-supply needs of the area.

The thick glaciofluvial deposits which are present in the Oak Ridges Moraine and interfinger with the tills of the South Slope, constitute one of the largest aquifer complexes in south-central Ontario. The Oak Ridges Moraine acts as the recharge area for this aquifer complex, discharge occurring along the sharp topographic break of the South Slope and along incised stream valleys.

The discontinuous glaciofluvial and glaciolacustrine deposits of the Middle Drift Unit, found at depth in the Oak Ridges and South Slope areas, act as important aquifers in the South Slope and Lake Plain.

Both the Lake Iroquois coarse-grained deposits and the channel sand and gravel provide water supplies. These deposits are essentially linear in shape, consist of well-sorted and permeable sediments and are limited in areal extent. Channel sand and gravel supplies the water needs of the community of Newcastle.

The hydrogeologic properties of the bedrock and overburden are estimated by different methods. The resultant means and ranges of the coefficients of permeability and transmissibility are presented below:

Material - method	Coefficient of Permeability (Igpd/ft^2) Range	Coefficient of Transmissibility (Igpd/ft) Range (mean)
Upper Drift Unit-till		
-pumping tests	8-57	73-573
-specific capacity values	- - -	20-6000 (1050)
Channel Sand and Gravel		
-pumping tests	250-1125	1000-5500
-specific capacity values	- - -	20-7000 (1500)
Upper and Middle Drift Units - sand and gravel		
-pumping tests	750-810	7500-35200
-specific capacity values	- - -	20-40000 (3400)
-grain-size distribution	85-10000	- - -
Upper and Middle Drift Units - sand		
-grain-size distribution	12-810	- - -
Upper and Middle Drift Units - silt		
-grain-size distribution	4-15	- - -
Lindsay Formation - limestone		
-specific capacity values	- - -	20-8500 (730)
Whitby Formation - shale		
-specific capacity values	- - -	120-500 (230)

The direction of ground-water movement in the basin is, for the most part, down the regional slope from the Oak Ridges Moraine southward towards Lake Ontario. The water-level contour map is a subdued replica of the topographic surface map.

The vertical direction of ground-water movement as established from piezometer nests is downward in most areas of the basin. Some flowing wells occur along the sharp topographic break of the South Slope. These wells appear to be finished in lenses of sands and gravels which extend southwards from the Oak Ridges.

Water-level fluctuations in the basin follow a seasonal pattern, with a rise in levels during the late winter and spring and a decline during summer and fall. Based on long-term water-level measurements, there has been a gain in the amount of water in storage from 1966-1974. This gain is most noticeable in the western portion of the Oak Ridges Moraine where a measured water-level rise of 5.6 foot occurred.

A simplified hydrologic budget was calculated for the different sub-basins for a period of study spanning from four to seven years, by balancing the following equation:

$$P = R_S + Rg + Et \pm S$$

where:

P = total precipitation,

R_S = surface runoff,

Rg = ground-water runoff or baseflow,
Et = evapotranspiration
S = change in water in storage

The mean annual precipitation for the interval 1967-68 to 1973-74 is 35.75 inches at Tyrone, 33.40 inches at Orono and 30.93 inches at Bowmanville. Baseflow, estimated from the total streamflow, ranged from 21.7% for a sub-basin in the Lake Plain to 88.2% of the total streamflow for a sub-basin in the Oak Ridges Moraine. The mean evapotranspiration estimated from temperature data generated at the different meteorological stations in the basin ranged from 21.90 to 22.88 inches per year for the period of study.

The potential quantity of ground water available for use, as estimated from the hydrologic budgets, is approximately 8.9 to 11.2 inches of water/square mile/year (129 to 162 million Imperial gallons/square mile/year) for the northern portion of the basin and about 3 inches of water/square mile/year (43 million Imperial gallons/square mile/year) for the southern reaches. This assumes that all ground-water discharge can be diverted to wells. The actual amount would be somewhat less.

Ground water is used extensively in the basin for water-supply purposes. The favourable hydrogeologic conditions have resulted in a high rate of success in the drilling of wells and in obtaining of satisfactory supplies of water.

A total of 23 permits to take water have been issued in the basin for water takings in excess of 10,000 Igpd. The allowable takings amount to 4.8 mIgpd from the ground and surface water in the basin and an additional 3.9 mIgpd from Lake Ontario. The rural domestic water demand in the basin is estimated to be an additional 0.9 mIgpd. Three communities have municipal water-supply systems; these are Bowmanville, Newcastle and Orono. Newcastle and Orono use ground-water supplies exclusively while Bowmanville uses a combined ground- and surface-water supply.

A total of 154 water samples were collected in 1968 and 1971 from various wells, streams and springs in the area and analysed for their inorganic chemical content at the MOE laboratory. The following trends are observed in the examination of the analyses:

1. There is a general increase in the concentration of specific ions and total dissolved solids in the ground and surface water from north to south in the basin.
2. There is a progressive change in the relative ratios (e.g. Ca/Mg, HCO_3/Cl, and SO_4/Cl) of specific ions in the ground water from north to south.

With certain localized exceptions, the majority of the water samples collected in the basin lie within the recommended quality criteria standards for municipal, domestic and agricultural uses.

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APPENDIX A

MONTHLY PRECIPITATION AND TEMPERATURE DATA

BOWMANVILLE - MOSTERT STATION

	1967	1968	1969	1970	1971	1972	1973	1974
JANUARY		23.6 - 8.5 2.76-R	28.2-14.7 2.49	21.3-2.5 1.46	24.4-6.9 1.23	31.2-13.0 0.85	31.3-16.9 1.39	30.0-13.4 2.4
FEBRUARY		25.4-9.8 1.33-R	32.0-18.1 .49	28.6-12.4 1.17	30.4-16.3 3.15	27.6- 9.4 2.26	28.4-10.8 1.33	26.5-9.4 1.40
MARCH		40.4-23.2 2.13-R	36.3-21.3 1.25	35.9-21.1 2.06	33.7-19.3 1.07	33.1-17.6 3.2	46.3-30.9 4.22	37.3-22.0 2.27
APRIL		54.8-33.7 .98-R	53.7-33.5 3.53	53.1-33.1 2.63	49.4-31.7 1.17	45.9-29.1 2.67	51.6-35.0 2.74	33.6-53.2 3.28
MAY		58.8-41.1 3.70-R	60.3-40.2 3.29	61.4-42.3 2.62	63.0-40.7 1.31	- 2.12	59.7-42.8 3.77	58.8-40.5 3.72
JUNE		69.8-50.8 2.43-R	71.4-51.1 2.46	72.9-49.9 2.68	71.8-50.8 4.28	69.0-50.1 3.15	74.2-54.0 2.24	70.7-51.2 3.90
JULY		74.7-54.8 .38-R	76.7-56.6 4.28	76.6-58.1 2.98	77.6-53.9 2.51	76.1-55.7 3.21	79.1-57.2 1.44	77.1-55.9 3.44
AUGUST		75.3-54.5 2.96-R	77.8-56.1 4.02	77.6-54.6 1.19	74.7-52.1 4.02	72.7-5.45 4.34	80.2-59.0 2.04	76.3-54.3 1.83
SEPTEMBER		70.8-51.7 2.41-R	69.0-43.9 0.8	68.9-49.4 1.64	71.2-52.6 1.78	68.9-49.9 2.52	70.8-46.7 1.72	66.3-44.9 2.74
OCTOBER	57.8-38.95 3.11	58.9-40.0 2.18-R	55.4-37.8 2.52	58.3-42.7 5.16	62.9-43.6 2.57	51.6-35.2 3.08	59.5-40.7 4.26	
NOVEMBER	40.3-28.4 2.91-R	43.0-29.9 4.52-R	- 3.82	46.5-34.1 2.05	43.4-29.6 2.16	40.6-30.1 2.98	44.8-32.2 3.11	
DECEMBER	35.1-23.3 2.38-R	30.1-16.7 3.54	26.3-15.0 2.30	28.6-14.2 2.41	36.5-21.2 4.00	33.0-19.8 4.45	31.9-18.3 2.42	

Temperature - range ^{o}F
Precipitation - inches
R - estimated

TYRONE STATION

	1967	1968	1969	1970	1971	1972	1973	1974
JANUARY		22.3 - 6.6 2.40	26.9-11.8 2.86	19.9-1.5 2.04	22.4-4.5 2.91	29.6- 9.9 2.33	29.8-14.0 1.63	28.1-11.5 2.61
FEBRUARY		23.3 - 7.9 1.82	30.2-16.0 .72	21.7-7.8 1.26	29.1-13.2 4.37	25.4- 6.3 3.81	27.1- 8.8 1.60	24.6- 6.5 2.27
MARCH		40.1 -21.7 2.40	34.2-19.6 1.50	33.9-19.0 2.85	32.5-16.9 3.24	32.0-15.1 4.88	44.8-30.2 4.64	35.2-19.7 3.03
APRIL		35.9-35.0 1.02	52.9-34.2 3.61	53.9-33.7 3.04	48.10-30.3 1.27	45.5-27.6 2.74	51.8-33.5 3.90	54.2-33.6 3.67
MAY		59.2-42.3 4.28	62.2-41.2 3.47	63.3-43.1 2.5	63.2-41.6 1.19	67.1-44.5 2.00	60.3-42.1 4.94	59.0-39.8 4.64
JUNE	76.1-56.4 5.10	71.3-52.2 2.41	67.7-49.6 2.49	74.4-51.0 1.50	75.3-52.0 5.24	70.3-50.7 3.36	75.1-54.9 2.76	71.9-51.0 3.67
JULY	76.7-56.4 4.39	78.0-55.6 1.04	77.1-56.7 4.43	77.9-58.3 3.92	75.1-34.2 3.47	77.8-57.1 3.78	80.1-57.5 1.60	78.1-56.3 3.02
AUGUST	74.8-55.6 2.59	76.2-55.9 3.59	78.5-56.6 3.47	78.4-55.8 1.28	75.7-54.0 2.30	74.3-54.9 4.81	81.1-59.6 3.46	77.2-54.5 2.02
SEPTEMBER	68.6-47.0 3.09	71.0-52.6 3.45	69.2-48.6 0.44	68.5-50.0 2.93	71.3-52.6 2.65	69.1-49.7 3.51	70.1-47.0 2.11	66.1-44.2 2.65
OCTOBER	55.0-39.1 3.42	58.3-40.8 2.22	- 3.16	58.4-43.4 4.00	63.9-44.8 1.83	51.3-33.5 3.98	59.5-41.1 4.81	
November	38.5-27.1 3.80	41.1-29.3 4.46	43.2-31.5 3.73	44.6-33.2 2.71	41.5-28.1 2.37	38.7-28.4 2.86	43.1-30.4 4.42	
DECEMBER	33.2-20.9 2.67	28.2-15.1 3.26	26.3-13.6 2.34	26.9-13.9 2.90	35.2-19.9 4.37	32.0-17.6 4.58	29.8-16.1 3.17	

Temperature - range $^{\circ}F$
Precipitation - inches

ORONO - PROVINCIAL FOREST STATION

	1967	1968	1969	1970	1971	1972	1973	1974
JANUARY	33.1-18.2	24.1 - 7.8	27.9-13.0	21.0-3.8	23.7-6.6	30.0-10.7	29.6-14.7	28.9-11.2
	2.78	2.88	2.55	2.57	2.30	1.75	1.65	3.58
FEBRUARY	25.4- 7.1	25.8- 8.8	31.1-16.7	27.8-8.5	30.0-5.1	27.0- 7.5	27.7- 8.0	26.1-7.7
	2.14	2.16	0.82	2.49	4.50	3.05	1.30	1.79
MARCH	36.0-20.2	41.7 -22.9	35.4-19.5	35.0-20.8	33.0-17.7	32.7-16.6	45.6-29.8	36.5-20.3
	.94	2.28	1.19	2.46	1.15	3.55	3.34	4.09
APRIL	51.2-29.0	56.8-39.0	54.6-34.1	55.0-33.5	48.6-29.7	46.4-27.6	51.8-33.2	55.3-33.0
	3.29	1.04	3.49	2.38	1.13	2.98	3.55	2.99
MAY	57.3-34.8	60.7-42.8	68.1-41.2	64.0-42.7	64.1-38.9	67.2-42.0	60.3-41.8	59.7-39.5
	2.84	3.97	3.33	3.34	1.00	2.17	3.90	4.21
JUNE	77.1-56.3	73.0-51.8	70.7-50.60	74.3-49.5	74.1-49.4	70.4-48.7	75.2-53.4	72.3-51.6
	5.60	2.14	2.34	2.79	4.55	3.12	2.96	3.46
JULY	76.1-56.9	80.0-56.0	78.2-57.4	78.6-58.0	76.7-53.7	78.3-55.0	80.1-57.6	78.2-56.6
	3.42	0.38	4.30	4.50	2.79	3.99	1.13	4.22
AUGUST	75.5-55.8	77.6-55.0	79.9-57.2	79.1-56.6	75.8-51.8	74.3-54.1	81.7-59.4	77.7-56.1
	1.94	2.60	2.24	1.45	2.91	5.41	1.72	1.91
SEPTEMBER	70.0-47.9	72.1-52.6	69.7-48.7	69.9-49.0	71.3-51.4	69.4-49.3	70.4-47.3	66.2-45.7
	2.99	2.35	.35	2.45	1.68	2.99	1.81	
OCTOBER	56.0-40.0	59.0-40.9	55.6-38.0	57.6-39.2	63.6-44.2	51.4-32.6	59.8-39.7	
	3.61	2.09	2.66	4.35	2.18	2.91	3.17	
NOVEMBER	39.6-6-27.6	42.1-29.7	44.2-32.1	45.2-32.2	41.6-25.0	39.0-27.0	43.9-30.4	
	3.70	4.79	3.54	2.51	2.61	2.68	3.98	
DECEMBER	34.8-22.3	28.5-15.6	27.5-14.5	27.8-12.6	35.0-20.3	31.9-17.5	29.7-16.9	
	3.02	3.46	2.42	3.56	3.57	5.33	1.91	

Temperature - range ^{o}F
Precipitation - inches

APPENDIX B

MOE OBSERVATION - WELL LOGS

Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Darlington	IX	21

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 19 MO 3 YR 66

Well # B-1

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
light brown	till	silty		0	26
light brown	till	sandy		26	38
gray-brown	till	silty		38	82
light brown	till	sandy		82	96
light brown	sand			96	115
gray-brown	till	silty	fine grained sand	115	206

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
187	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	187
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
#18	6 INCHES	4 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
stainless steel	187 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☒ BAILER	8 GPM	8 HOURS ___ MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
121 FEET	156 FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE ___ GPM | PUMP INTAKE SET AT ___ FEET | WATER AT END OF TEST ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE ☐ SHALLOW ☐ DEEP | RECOMMENDED PUMP SETTING ___ FEET | RECOMMENDED PUMPING RATE ___ GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd. LICENCE NUMBER:

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER: B. Burgess LICENCE NUMBER:

SIGNATURE OF CONTRACTOR: SUBMISSION DATE DAY ___ MO ___ YR ___

OFFICE USE ONLY

OWNER'S COPY

FORM NO. 0506-4-77

Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY XXXXXX	TOWNSHIP XXXXXXXXXXXXXXXX	CON XXXXXXXXXXXXXXX	LOT
Durham	Darlington	VII	21

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 22 MO 4 YR 66

Well # B-2

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
	till	sandy	leached zone	0	14
	sand & gravel			14	15
	till	silty		15	38

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
20	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	15
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	5 INCHES	5 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted casing	15 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
20	38	back filled

PUMPING TEST

PUMPING TEST METHOD: ☐ PUMP ☐ BAILER	PUMPING RATE: GPM	DURATION OF PUMPING: HOURS MINS
STATIC LEVEL: 16 FEET	WATER LEVEL END OF PUMPING: FEET	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY — 15 MINUTES: FEET; 30 MINUTES: FEET; 45 MINUTES: FEET; 60 MINUTES: FEET
IF FLOWING GIVE RATE: GPM	PUMP INTAKE SET AT: FEET	WATER AT END OF TEST: ☐ CLEAR ☐ CLOUDY
RECOMMENDED PUMP TYPE: ☐ SHALLOW ☐ DEEP	RECOMMENDED PUMP SETTING: FEET	RECOMMENDED PUMPING RATE: GPM

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW

DRILLERS REMARKS

FINAL STATUS OF WELL

☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE

☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☐ ROTARY (REVERSE)
☒ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd.	LICENCE NUMBER
ADDRESS: Peterborough, Ont.	
NAME OF DRILLER OR BORER: B. Burgess	LICENCE NUMBER
SIGNATURE OF CONTRACTOR	SUBMISSION DATE: DAY MO YR

OFFICE USE ONLY

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FORM NO. 0506-4-77

Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Darlington	II	12

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 15 MO 4 YR 66

Well # B-4

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	fill			0	10
	till	clay		10	95
	till	silty		95	101
	till	clay		101	106
	till	silty		106	111
	till	clay		111	116
	limestone			116	117

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
116	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
1.5	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	28
1.5	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	120
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	1.5 INCHES	5 / 3 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted pipe	20 / 114 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
		6" casing collar
109	117	gravel
107	109	macogel seal

PUMPING TEST

PUMPING TEST METHOD ☐ PUMP ☐ BAILER | PUMPING RATE GPM | DURATION OF PUMPING HOURS MINS

STATIC LEVEL: 28' well-5.4; 120' well-17 (WATER LEVEL END OF PUMPING) FEET

WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES FEET | 30 MINUTES FEET | 45 MINUTES FEET | 60 MINUTES FEET

IF FLOWING, GIVE RATE GPM | PUMP INTAKE SET AT FEET | WATER AT END OF TEST ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE ☐ SHALLOW ☐ DEEP | RECOMMENDED PUMP SETTING FEET | RECOMMENDED PUMPING RATE GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd. | LICENCE NUMBER

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER: T. Urban | LICENCE NUMBER

SIGNATURE OF CONTRACTOR | SUBMISSION DATE DAY MO YR

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Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Darlington	VIII	5

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 4 MO 4 YR 66

Well # S-1a

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	till	silty		0	35
brown	sand		medium grained	35	40
brown	sand		fine grained	40	85

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
21	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
1.5	☒ GALVANIZED		0	16

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	1.5 INCHES	5 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted pipe	16 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
21	85	backfilled

PUMPING TEST

PUMPING TEST METHOD: ☐ PUMP ☐ BAILER

PUMPING RATE: GPM

DURATION OF PUMPING: HOURS MINS

STATIC LEVEL: 21 FEET

WATER LEVEL END OF PUMPING: FEET

WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES FEET; 30 MINUTES FEET; 45 MINUTES FEET; 60 MINUTES FEET

IF FLOWING GIVE RATE: GPM

PUMP INTAKE SET AT: FEET

WATER AT END OF TEST: ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☐ SHALLOW ☐ DEEP

RECOMMENDED PUMP SETTING: FEET

RECOMMENDED PUMPING RATE: GPM

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd.

LICENCE NUMBER:

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER: B. Burgess

LICENCE NUMBER:

SIGNATURE OF CONTRACTOR:

SUBMISSION DATE: DAY MO YR

OFFICE USE ONLY

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FORM NO. 0506-4-77

Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Darlington	VIII	5

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 27 MO 4 YR 66

Well # S-1b

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
Brown	till	silty		0	35
Light brown	sand		medium grained	35	40
Light brown	sand		fine grained	40	104
Light brown	sand		medium grained	104	114
Light brown	sand		fine grained	114	145
	gravel		medium - coarse grained	145	165

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
165	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	159
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER INCHES	LENGTH FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN FEET
open end casing	

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	GPM	HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
147 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR	LICENCE NUMBER
Faulkner Well Drilling Co. Ltd.	

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER	LICENCE NUMBER
B. Burgess	

SIGNATURE OF CONTRACTOR — SUBMISSION DATE DAY ___ MO ___ YR ___

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Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Darlington	IV	6

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 29 MO 3 YR 66

Well # S-4

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	sand		medium grained	0	5
	sand		very fine grained	5	54
Grey	till	silty		54	95
Light Grey	till	silty		95	105
Grey Brown	till	silty		105	151
	limestone			151	158

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
49	☒ FRESH
125	☒ FRESH
157	☒ FRESH

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
1.5	☒ GALVANIZED		0	162
			0	132
			0	52

SCREEN

SIZE(S) OF OPENING (SLOT NO.):
DIAMETER: 1.5 INCHES
LENGTH: 3 / 9 / 10 FEET
MATERIAL AND TYPE: slotted pipe
DEPTH TO TOP OF SCREEN: 156 / 120 / 39 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
39	49	gravel pack/Macogel seal
120	129	
155	159	

PUMPING TEST

PUMPING TEST METHOD: ☐ PUMP ☐ BAILER
PUMPING RATE: GPM
DURATION OF PUMPING: HOURS MINS

STATIC LEVEL / WATER LEVEL END OF PUMPING:
159' well -37
128' well -37
49' well -15

WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES FEET, 30 MINUTES FEET, 45 MINUTES FEET, 60 MINUTES FEET

IF FLOWING GIVE RATE: GPM
PUMP INTAKE SET AT: FEET
WATER AT END OF TEST: ☐ CLEAR ☐ CLOUDY
RECOMMENDED PUMP TYPE: ☐ SHALLOW ☐ DEEP
RECOMMENDED PUMP SETTING: FEET
RECOMMENDED PUMPING RATE: GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED INSUFFICIENT SUPPLY ☐ ABANDONED POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd.
LICENCE NUMBER:
ADDRESS: Peterborough, Ontario
NAME OF DRILLER OR BORER: B. Burgess
LICENCE NUMBER:
SIGNATURE OF CONTRACTOR:
SUBMISSION DATE: DAY MO YR

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WATER WELL RECORD

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COUNTY	TOWNSHIP	CON	LOT
Durham	Darlington	IV	6

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 30 MO 3 YR 66

Well # S-5

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
Brown	sand	silty till		0	42

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
37	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
1.5	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	33
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	1.5 INCHES	9 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted pipe	33 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER, ETC.)
		6" casing collar

PUMPING TEST

PUMPING TEST METHOD: ☐ PUMP ☐ BAILER | PUMPING RATE: GPM | DURATION OF PUMPING: HOURS MINS

STATIC LEVEL: 20 FEET | WATER LEVEL END OF PUMPING: FEET | WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES FEET, 30 MINUTES FEET, 45 MINUTES FEET, 60 MINUTES FEET

IF FLOWING GIVE RATE: GPM | PUMP INTAKE SET AT: FEET | WATER AT END OF TEST: ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☐ SHALLOW ☐ DEEP | RECOMMENDED PUMP SETTING: FEET | RECOMMENDED PUMPING RATE: GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE

☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☐ ROTARY (REVERSE)
☒ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd. | LICENCE NUMBER:

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER: B. Burgess | LICENCE NUMBER:

SIGNATURE OF CONTRACTOR: | SUBMISSION DATE: DAY MO YR

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WATER WELL RECORD

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COUNTY	TOWNSHIP	CON	LOT
Durham	Darlington	II	7

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 17 MO 3 YR 66

Well # S-6a

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
Brown	till	silty clay	oxidized zone	0	5
Grey	till	silty sandy		5	14
	till	sandy clay		14	26
	limestone			26	32

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
14-26	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
32	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	29
6	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☒ OPEN HOLE		29	32
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	INCHES	3 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
open hole in rock	29 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)

PUMPING TEST

PUMPING TEST METHOD	☒ PUMP ☐ BAILER
PUMPING RATE	GPM
DURATION OF PUMPING	1 HOURS MINS
STATIC LEVEL	7.3 FEET
WATER LEVEL END OF PUMPING	FEET
WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY	15 MINUTES FEET / 30 MINUTES FEET / 45 MINUTES FEET / 60 MINUTES FEET
IF FLOWING GIVE RATE	GPM
PUMP INTAKE SET AT	FEET
WATER AT END OF TEST	☐ CLEAR ☐ CLOUDY
RECOMMENDED PUMP TYPE	☐ SHALLOW ☐ DEEP
RECOMMENDED PUMP SETTING	FEET
RECOMMENDED PUMPING RATE	GPM

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

FINAL STATUS OF WELL
☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE
☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING
☐ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☐ ROTARY (REVERSE)
☒ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

CONTRACTOR

NAME OF WELL CONTRACTOR	Faulkner Well Drilling Co. Ltd.
LICENCE NUMBER	
ADDRESS	Peterborough, Ontario
NAME OF DRILLER OR BORER	B. Burgess
LICENCE NUMBER	
SIGNATURE OF CONTRACTOR	
SUBMISSION DATE	DAY MO YR

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Ontario

The Ontario Water Resources Act

WATER WELL RECORD

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2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY OR [district]	TOWNSHIP	CON	LOT
Durham	Darlington	II	7

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 18 MO 3 YR 66

Well # S-6b

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	Till	Silty clay		0	5
	Till	Clay		5	14
	Till	Sandy clay		14	24

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
14-24	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
1.5	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	27
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	1.5 INCHES	10 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
Slotted pipe	14 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
		6" casing collar
14	24	Gravel pack/Macogel seal

PUMPING TEST

PUMPING TEST METHOD ☐ PUMP ☐ BAILER | PUMPING RATE ___ GPM | DURATION OF PUMPING ___ HOURS ___ MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
6.5 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE ___ GPM | PUMP INTAKE SET AT ___ FEET | WATER AT END OF TEST ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE ☐ SHALLOW ☐ DEEP | RECOMMENDED PUMP SETTING ___ FEET | RECOMMENDED PUMPING RATE ___ GPM

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

FINAL STATUS OF WELL

☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE

☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☐ ROTARY (REVERSE)
☒ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd. | LICENCE NUMBER

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER: B. Burgess | LICENCE NUMBER

SIGNATURE OF CONTRACTOR | SUBMISSION DATE DAY ___ MO ___ YR ___

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Ontario

The Ontario Water Resources Act

WATER WELL RECORD

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2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Clarke	V	35

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 29 MO 4 YR 66

Well #S -7

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
Light brown	sand		medium grained	0	20
	till	sandy		20	40
Light brown	sand		very fine grained	40	55

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
45-55	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☒ GALVANIZED		0	45

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	5 INCHES	10 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
Slotted casing	43 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☒ BAILER	1.5 GPM	2 HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
37.3 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE ___ GPM · PUMP INTAKE SET AT ___ FEET · WATER AT END OF TEST ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE ☐ SHALLOW ☐ DEEP · RECOMMENDED PUMP SETTING ___ FEET · RECOMMENDED PUMPING RATE ___ GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd. LICENCE NUMBER:

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER: B. Burgess LICENCE NUMBER:

SIGNATURE OF CONTRACTOR · SUBMISSION DATE DAY ___ MO ___ YR ___

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Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY OR DISTRICT	TOWNSHIP	CON.	LOT
Durham	Clarke	VIII	31

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 19 MO 1 YR 66

Well # W-1

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
brown	till	sandy		0	13
brown	sand		fine to medium grained	13	14
brown	sand	silty		14	40
brown	sand		fine to medium grained	40	47
brown	till	sandy		47	56
brown	sand			56	66
brown	till	sandy		66	81
	sand		medium grained	81	82
brown	till	sandy		82	111
	sand			111	112
grey	till	silty		112	150

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
120-126	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	117
5	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		117	130
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	5 INCHES	13 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted pipe	117 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER, ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☒ PUMP ☐ BAILER	3 GPM	15 HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
48.5 FEET	61 FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☒ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR	LICENCE NUMBER
Faulkner Well Drilling Co. Ltd.	

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER	LICENCE NUMBER
B. Burgess	

SIGNATURE OF CONTRACTOR	SUBMISSION DATE
	DAY MO YR

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Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY OR DISTRICT	TOWNSHIP	CON	LOT
Durham	Clarke	VII	31

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 23 MO 3 YR 66

Well # W-2

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	* see attached log				

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
113-129	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
235	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
465-494	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
502	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
507	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	170
4	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	507
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER INCHES	LENGTH FEET
		5

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN FEET
open hole in rock	502

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	GPM	HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
25 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING, GIVE RATE: GPM — PUMP INTAKE SET AT: FEET — WATER AT END OF TEST: ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☐ SHALLOW ☐ DEEP — RECOMMENDED PUMP SETTING: FEET — RECOMMENDED PUMPING RATE: GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE

☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING

☒ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☒ ROTARY (REVERSE)
☐ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd. — LICENCE NUMBER:

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER: Ed Taylor — LICENCE NUMBER:

SIGNATURE OF CONTRACTOR — SUBMISSION DATE: DAY MO YR

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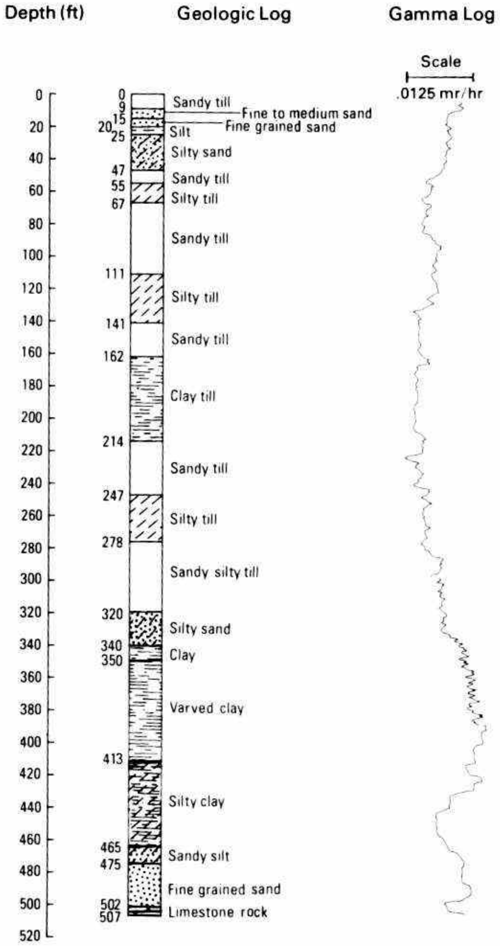
FORM NO. 0506-4-77

Composite log of Observation Well W-2.



Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1 PRINT ONLY IN SPACES PROVIDED
2 CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Clarke	V	32

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 16 MO 3 YR 66

Well # W-3

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	sand & gravel			0	14
	sand		fine grained	14	81
	till	silty		81	124
	sand	silty		124	129
grey	clay			129	132
	till	clay		132	166
	limestone			166	214

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
63-66	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
154-156	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	153
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
#8	6 INCHES	4 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
	153 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☒ PUMP ☐ BAILER	20 GPM	2.5 HOURS ___ MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
57 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☐ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR	LICENCE NUMBER
Faulkner Well Drilling Co. Ltd.	

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER	LICENCE NUMBER
B. Burgess	

SIGNATURE OF CONTRACTOR	SUBMISSION DATE
	DAY ___ MO ___ YR ___

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Ontario

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WATER WELL RECORD

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COUNTY	TOWNSHIP	CON.	LOT
Durham	Clarke	VI	22

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 8 MO 4 YR 66

Well # W-5a

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	till	silty		0	30
	till	sandy		30	41
	sandy & gravel		coarse grained sand	41	45
	till	silty		45	72
	till	sandy		72	152

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
25	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
41 - 46	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
143-148	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
1.5	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0 0 0	28 49 151
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		49	110
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	1.5 INCHES	5 5 3 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted pipe	148 43 23 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER ETC.)
143	148	gravel pack/macogel seal
43	46	" " " "
23	26	" " " "
		6" casing collar

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	GPM	HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
28' well	6.2	FEET	FEET	FEET	FEET
49' well	-6.6				
151' well	-flows FEET				

IF FLOWING, GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE

☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING

☒ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☐ ROTARY (REVERSE)
☐ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR	LICENCE NUMBER
Faulkner Well Drilling Co. Ltd.	

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER	LICENCE NUMBER
Ed Taylor	

SIGNATURE OF CONTRACTOR	SUBMISSION DATE
	DAY MO. YR.

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Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Clarke	VI	22

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 22 MO 4 YR 66

Well # W-5b

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	till	silty		0	24
	till	sandy		24	36
	sand & gravel			36	47

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
36-47	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	36
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	5 INCHES	9 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted casing	36 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	GPM	HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
7.3 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Faulkner Well Drilling Co. Ltd.	LICENCE NUMBER
ADDRESS: Peterborough, Ontario	
NAME OF DRILLER OR BORER: Ed Taylor	LICENCE NUMBER
SIGNATURE OF CONTRACTOR	SUBMISSION DATE DAY MO YR

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Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY OR XXXXXX	TOWNSHIP XXXXXXXXXXXXXXXXXX	CON XXXXXXXXXXXXXXX	LOT
Durham	Clarke	II	32

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 15 MO 3 YR 66

Well # W-7

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	till	clay	oxidized zone (0-5)	0	12
	till	silty		12	25
	sand & gravel			25	30
	limestone			30	36

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
25-30	☒ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	25
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	5 INCHES	5 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted casing	25 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	GPM	HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
11 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE

☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☐ ROTARY (REVERSE)
☒ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR	LICENCE NUMBER
Faulkner Well Drilling Co. Ltd.	

ADDRESS: Peterborough, Ontario

NAME OF DRILLER OR BORER	LICENCE NUMBER
B. Burgess	

SIGNATURE OF CONTRACTOR	SUBMISSION DATE
	DAY MO. YR.

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Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Clarke	X	28

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 7 MO 3 YR 68

Well # W-8

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	*see attached log				

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
184-206	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
396-406	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
628-708	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	7
1.5	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0 0 0	708 398 240
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING / MATERIAL AND TYPE	DIAMETER INCHES	LENGTH FEET	DEPTH TO TOP OF SCREEN FEET
708'-slotted pipe 398'-sand point 240'-sand point			

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER ETC.)
708		Gravel & sand pack
398 240		Cement plug

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	GPM	HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY: 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
398ft- 90 FEET	FEET	FEET	FEET	FEET	FEET
240ft-150					

IF FLOWING GIVE RATE GPM — PUMP INTAKE SET AT FEET — WATER AT END OF TEST ☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE ☐ SHALLOW ☐ DEEP — RECOMMENDED PUMP SETTING FEET — RECOMMENDED PUMPING RATE GPM

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.

FINAL STATUS OF WELL: ☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE: ☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING: ☐ CABLE TOOL ☒ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☐ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

*Lost 2000 gallons of mud at 396-406 ft.

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR: Snider Drilling — LICENCE NUMBER

ADDRESS: Craighurst, Ontario

NAME OF DRILLER OR BORER — LICENCE NUMBER

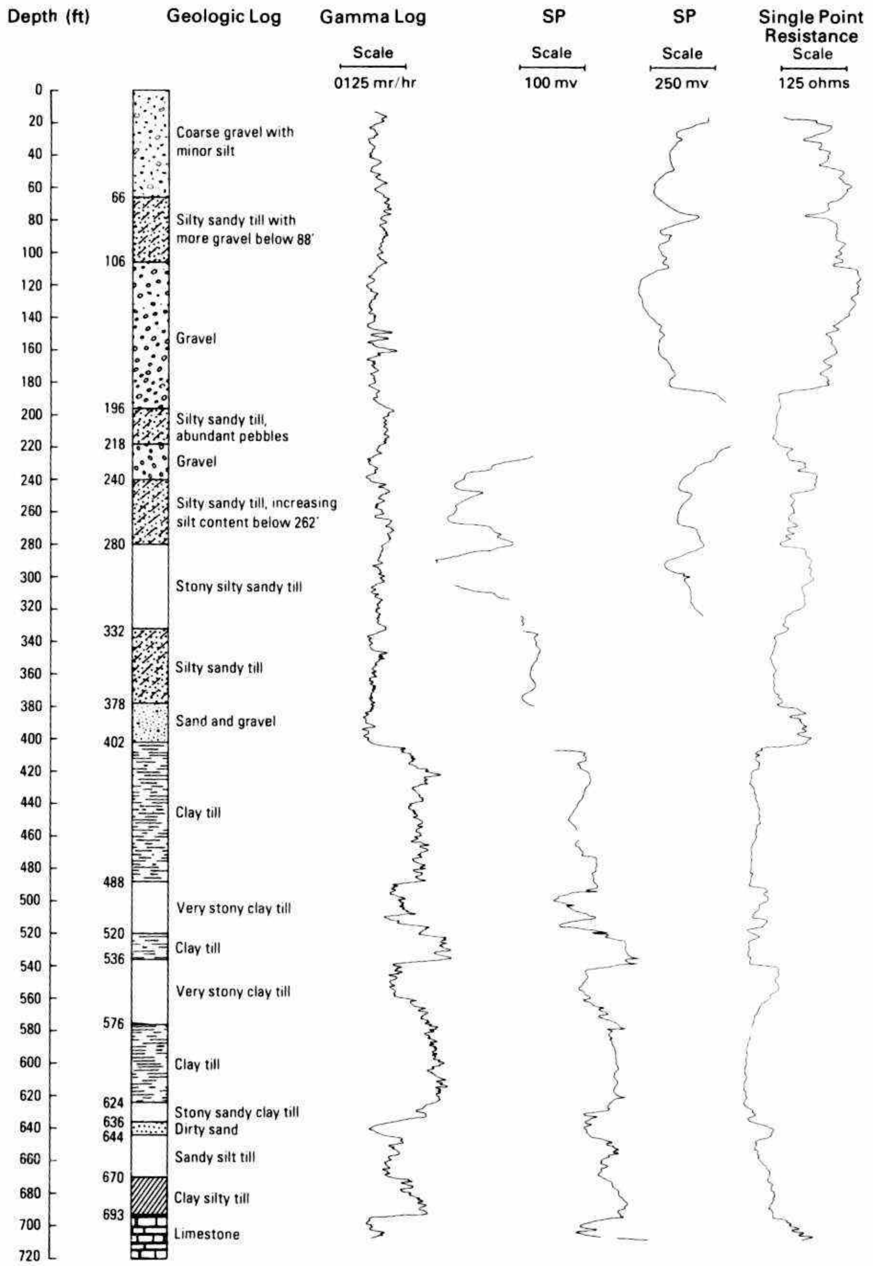
SIGNATURE OF CONTRACTOR — SUBMISSION DATE DAY MO YR

OFFICE USE ONLY

 OWNER'S COPY

FORM NO. 0506-4-77

Composite log of Observation Well W-8.



Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1 PRINT ONLY IN SPACES PROVIDED
2 CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY	TOWNSHIP	CON	LOT
Durham	Clarke	X	28

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 18 MO 4 YR 68

Well # W-9

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
	Sand	Gravel & Boulders	Dirty	0	20
	Sand & Gravel			20	192
Grey	Till	Silty		192	199
	Sand & Gravel		with some silty lenses	199	290
	Till	Silty sandy		290	335
	Sand	Silt lense @ 360'	Fine to medium grained	335	379
	Till	Silty sandy		379	383
	Sand & Gravel			383	391
	Clay	Silty		391	401
	Sand & Gravel	Silty		401	403
	Till	Silty clay		403	411
	Clay			411	430

*see attached log

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
199-250	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
335-379	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
383-391	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	382
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
#12	6 INCHES	4 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
Stainless Steel	382 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT LEAD PACKER ETC.)
		5' x 5" ID Tail Pipe

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	≈ 10 GPM	1 HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
184 FEET	328 FEET	FEET	FEET	FEET	FEET

☐ PUMPING ☐ RECOVERY

IF FLOWING GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☐ CLEAR ☒ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW

DRILLERS REMARKS

FINAL STATUS OF WELL

☐ WATER SUPPLY
☒ OBSERVATION WELL
☐ TEST HOLE
☐ RECHARGE WELL
☐ ABANDONED, INSUFFICIENT SUPPLY
☐ ABANDONED, POOR QUALITY
☐ UNFINISHED

WATER USE

☐ DOMESTIC
☐ STOCK
☐ IRRIGATION
☐ INDUSTRIAL
☐ OTHER
☐ COMMERCIAL
☐ MUNICIPAL
☐ PUBLIC SUPPLY
☐ COOLING OR AIR CONDITIONING
☐ NOT USED

METHOD OF DRILLING

☒ CABLE TOOL
☐ ROTARY (CONVENTIONAL)
☐ ROTARY (REVERSE)
☐ ROTARY (AIR)
☐ AIR PERCUSSION
☐ BORING
☐ DIAMOND
☐ JETTING
☐ DRIVING

CONTRACTOR

NAME OF WELL CONTRACTOR: Goodberry Well Drilling Ltd.
LICENCE NUMBER:
ADDRESS: 196 Indian Road
KINGSTON, Ontario.
NAME OF DRILLER OR BORER: G. Babcock
LICENCE NUMBER:
SIGNATURE OF CONTRACTOR:
SUBMISSION DATE: DAY MO YR

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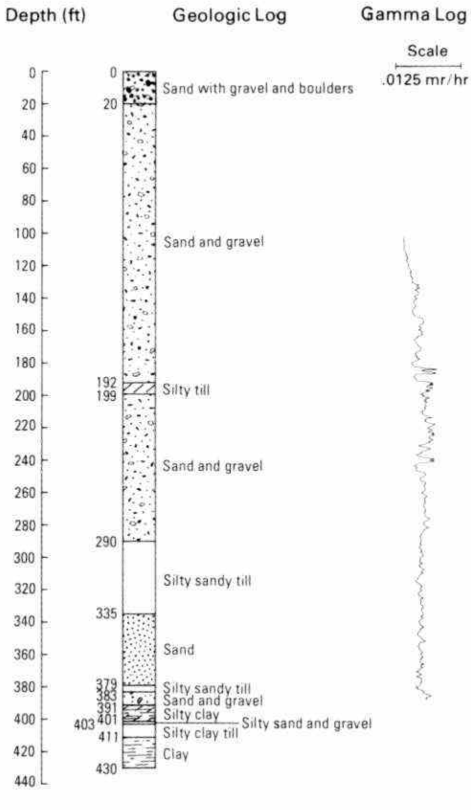
FORM NO. 0506-4-77

Composite log of Observation Well W-9.



Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY OR DISTRICT	TOWNSHIP	CON	LOT
Durham	Manvers	I	6

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
MOE		DAY 11 MO 3 YR 68

Well # W-10

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	* see attached log				

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
204-228	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
260-280	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
622-690	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL
	☐ FRESH ☐ SULPHUR ☐ SALTY ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
6	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	7
2	☐ STEEL ☒ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE		0	690
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER	LENGTH
	2 INCHES	5 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN
slotted pipe	685 FEET

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
685	690	Gravel and sand pack
685		cement plug
640		cement plug

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☐ PUMP ☐ BAILER	GPM	HOURS MINS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☐ PUMPING ☐ RECOVERY 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
120 FEET	FEET	FEET	FEET	FEET	FEET

IF FLOWING, GIVE RATE	PUMP INTAKE SET AT	WATER AT END OF TEST
GPM	FEET	☐ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
☐ SHALLOW ☐ DEEP	FEET	GPM

FINAL STATUS OF WELL

☐ WATER SUPPLY ☒ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED, POOR QUALITY ☐ UNFINISHED

WATER USE

☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED

METHOD OF DRILLING

☐ CABLE TOOL ☒ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☐ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW

DRILLERS REMARKS

CONTRACTOR

NAME OF WELL CONTRACTOR	LICENCE NUMBER
Snider Drilling	

ADDRESS: Craighurst, Ontario

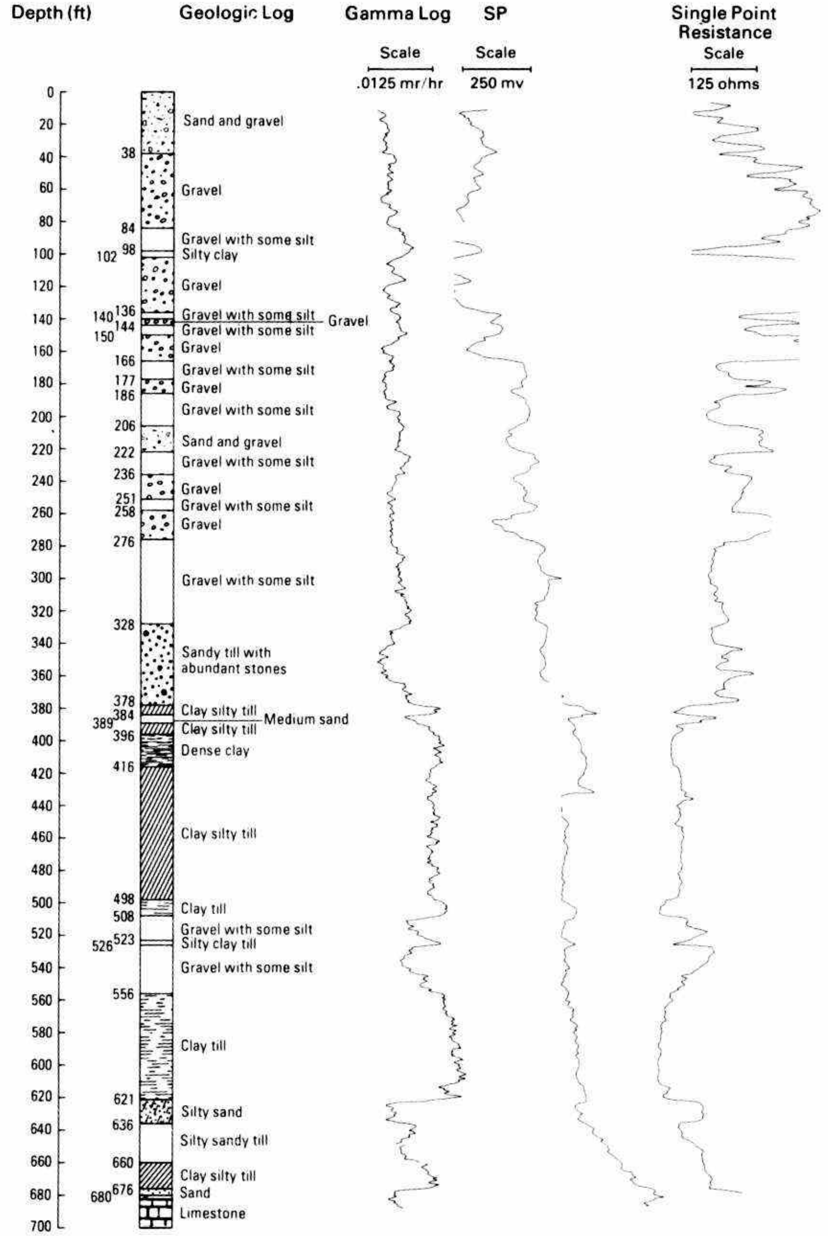
NAME OF DRILLER OR BORER	LICENCE NUMBER

SIGNATURE OF CONTRACTOR	SUBMISSION DATE
	DAY MO YR

OFFICE USE ONLY

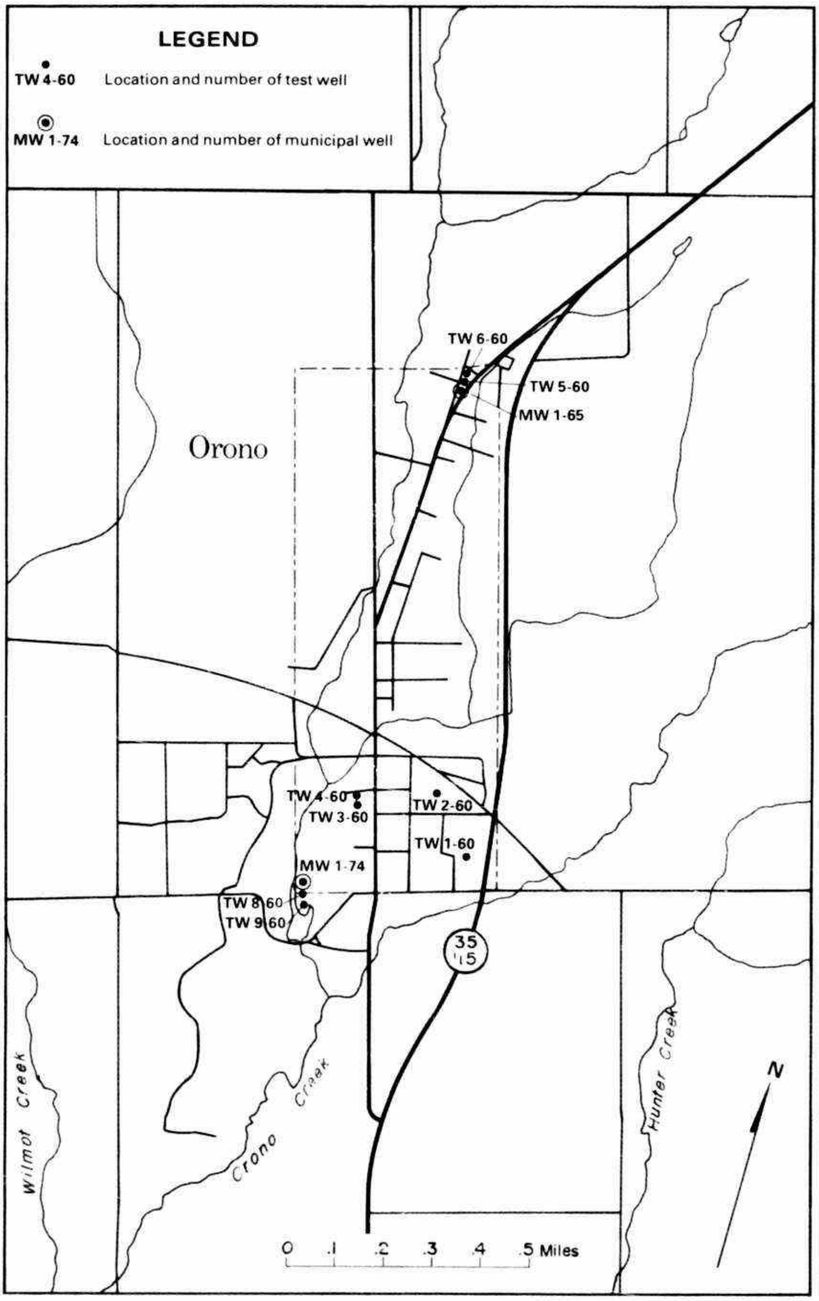
FORM NO. 0506-4-77

Composite log of Observation Well W-10.



APPENDIX C

LOCATION MAPS AND GEOLOGICAL LOGS FOR PUMPING
AND RECOVERY TESTS CONDUCTED IN THE BASIN
AT ORONO AND NEWCASTLE



Locations of test wells and municipal wells in Orono.

ORONO - DRILLERS' LOGS

TW 1/60

0 - 1 feet	Top soil
1 - 26 feet	Soft grey clay and boulders
26 - 32 feet	Dirty sand
32 - 36 feet	Boulders, cemented sand
36 - 42 feet	Cemented sand changing to clay
42 - 66 feet	Clay (hard)
66 -119 feet	Clay, gravel and boulders
119-121 feet	Sand and boulders
121-123 feet	Clay and gravel
123-127 feet	Tight sand, gravel and boulders
127-144 feet	Hard clay, gravel and boulders
144-148 feet	Shale changing to rock
148 feet	Rock

TW 2/60

0 - 1 feet	Top soil
1 - 10 feet	Sand and gravel
10 - 28 feet	Dirty sand and gravel changing to clay
28 - 36 feet	Dirty gravel and boulders
36 - 39 feet	Soft clay and boulders
39 - 42 feet	Gravel clay and boulders
42 - 51 feet	Soft clay and boulders changing to clay
51 - 59 feet	Soft silty clay
59 - 61 feet	Dirty gravel
61 - 67 feet	Clay and gravel
67 -139 feet	Clay gravel, odd boulders (hard)
139-147 feet	Shattered rock

TW 3/60

0 - 9 feet	Fill, boulders and sand
9 - 12 feet	Brown clay
12 - 19 feet	Sand and silt
19 - 21 feet	Brown clay

TW 4/60

0 - 9 feet	Fill boulders and sand
9 - 12 feet	Brown clay
12 - 19 feet	Sand and silt
19 - 23 feet	Brown clay
23 - 28 feet	Clay, small streaks of gravel
28 - 60 feet	Clay, gravel hard streaks
60 - 85 feet	Clay, gravel and boulders
85 - 95 feet	Hard clay and gravel
95 -101 feet	Shattered rock

TW 5/60

0 - 14 feet	Clay and gravel
14 - 30 feet	Silty clay
30 - 35 feet	Clay and gravel
35 - 42 feet	Gravel
42 - 48 feet	Clay
48 -100 feet	Clay and gravel
100-115 feet	Clay
115-138 feet	Clay and gravel
138-155 feet	Silty clay
155-189 feet	Clay and boulder
189 feet	Bedrock

TW 6/60

0 - 14 feet	Clay and gravel
14 - 30 feet	Silty clay
30 - 34 feet	Clay and gravel
31 - 42 feet	Gravel
42 - 47 feet	Clay

TW 8/60

0 - 1 feet	Topsoil
1 - 4 feet	Gravel and boulders
4 - 10 feet	Sand
10 - 17 feet	Silt, sand, clay and gravel
17 - 27 feet	Silt, clay showing
27 - 35 feet	Coarse sand, little clay showing
35 - 41 feet	Coarse sand
41 - 46 feet	Gravel
46 - 54 feet	Clay with sand
54 - 92 feet	Hardpan streaked with clay
92 - 94 feet	Clay
94 feet	Rock

TW 9/60

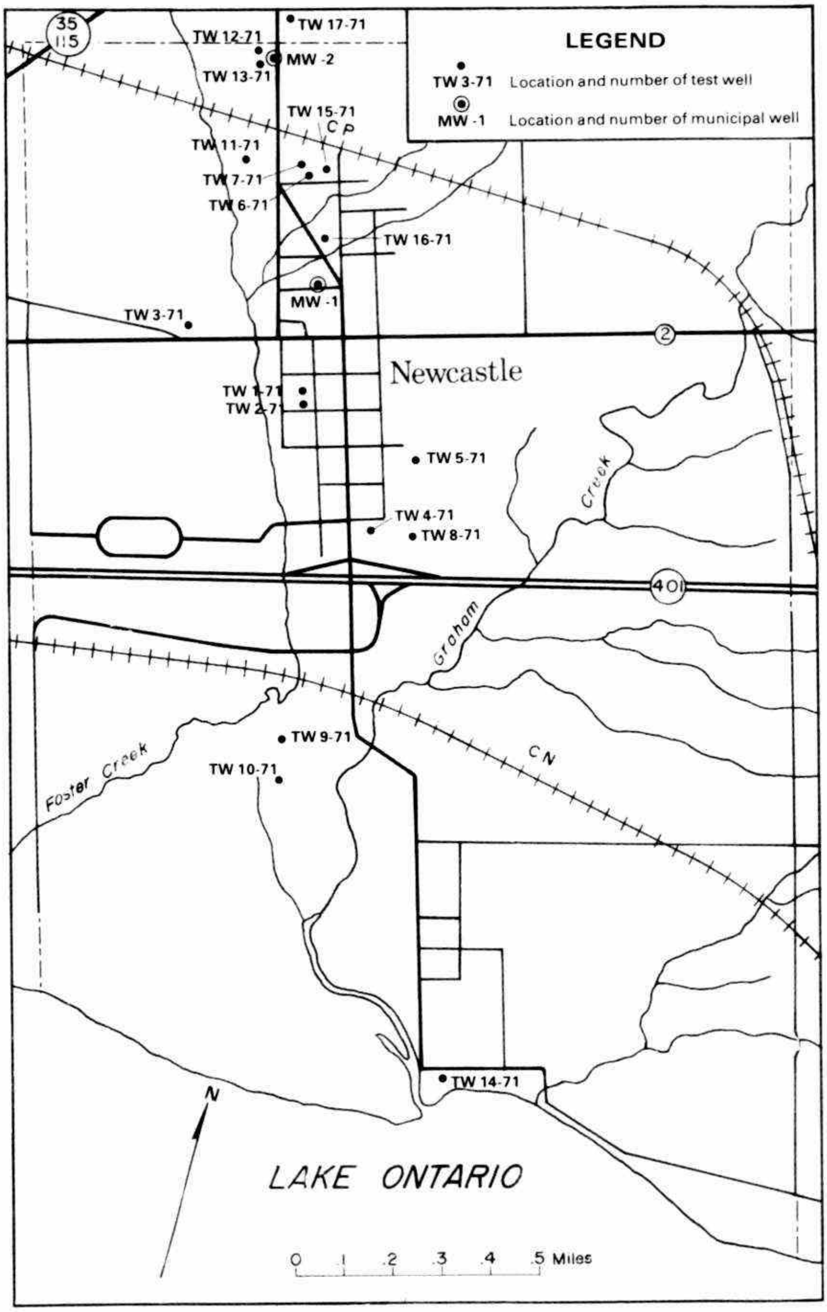
0 - 1 feet	Topsoil
1 - 3 feet	Gravel and boulders
3 - 7 feet	Sand
7 - 19 feet	Silt, sand, clay and gravel
19 - 27 feet	Silt, clay showing
27 - 35 feet	Coarse sand, lttle clay showing
35 - 41 feet	Coarse sand
41 - 45 feet	Gravel
45 - 49 feet	Clay with sand
49 - 51 feet	Hardpan streaked with clay

PW 1 - 65

0 - 2 feet	Sandy loam
2 - 19 feet	Brown sand with silt layers
19 - 22 feet	Silty clay with fine sand
22 - 34.3 feet	Fine sand and clay
34.3 - 35 feet	Coarse sand to gravel
35 - 36 feet	Coarse gravel
36 - 43 feet	Gravel
43 - 45 feet	Medium to fine sand
45 - 46 feet	Fine sand

PW 1 - 74

0 - 1 feet	Brown sandy gravel
1 - 30 feet	Brown and grey sand and clay
30 - 35 feet	Grey clay and stones
35 - 36 feet	Grey sand
36 - 47 feet	Brown coarse gravel
47 - 49 feet	Blue clay



Locations of test wells and municipal wells in Newcastle.

NEWCASTLE - DRILLERS' LOGS

TW 1/71

0 - 1 feet	Brown topsoil
1 - 31 feet	Brown clay
31 - 53 feet	Brown clay and stones
53 - 54 feet	Grey clay and gravel
54 - 78 feet	Grey limestone

TW 2/71

0 - 1 feet	Brown topsoil
1 - 31 feet	Brown clay
31 - 51 feet	Brown clay and stones
51 - 55 feet	Grey clay and sand
55 - 56 feet	Grey limestone

TW 3/71

0 - 1 feet	Brown topsoil
1 - 10 feet	Brown clay and stones
10 - 42 feet	Brown clay, sand and stones
42 - 44 feet	Brown clay and gravel
44 - 75 feet	Grey clay and stones
75 - 85 feet	Grey limestone

TW 4/71

0 - 1 feet	Brown topsoil
1 - 10 feet	Brown clay
10 - 20 feet	Brown clay and stones
20 - 30 feet	Grey clay
30 - 40 feet	Brown sandy clay and stones
40 - 42 feet	Brown sandy clay
42 - 45 feet	Brown sand and gravel
45 - 52 feet	Brown clay and shale rock
52 - 57 feet	Grey limestone

TW 5/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 44 feet	Grey clay and stones
44 - 47 feet	Grey sandy clay
47 - 50 feet	Grey sand and gravel
50 - 55 feet	Grey limestone

TW 6/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 42 feet	Grey clay
42 - 45 feet	Grey sandy clay
45 - 58 feet	Grey coarse sand and gravel

TW 7/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 45 feet	Grey clay
45 - 50 feet	Grey sandy clay and gravel
50 - 52 feet	Grey fine sand
52 - 57 feet	Grey coarse sand and gravel
57 - 58 feet	Grey limestone

TW 8/71

0 - 1 feet	Brown top soil
1 - 30 feet	Brown clay and stones
30 - 47 feet	Grey clay and stones
47 - 49 feet	Grey sandy clay
49 - 51 feet	Grey limestone

TW 9/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 45 feet	Grey clay and stones
45 - 51 feet	Grey limestone

TW 10/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 43 feet	Grey clay and stones
43 - 51 feet	Grey limestone

TW 11/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 55 feet	Grey clay
55 - 65 feet	Grey limestone

TW 12/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 45 feet	Grey clay and stones
45 - 54 feet	Brown sand and gravel
54 feet	Grey limestone

TW 13/71

0 - 1 feet	Brown topsoil
1 - 20 feet	Brown clay and stones
20 - 46 feet	Grey clay and stones
46 - 51'6"	Brown coarse sand and gravel
51'6" - 52 feet	Grey limestone

TW 14/71

0 - 1 feet	Brown topsoil
1 - 22 feet	Brown clay and stones
22 - 48 feet	Grey clay and stones
48 - 50 feet	Grey limestone

TW 15/71

0 - 1 feet	Brown topsoil
1 - 23 feet	Brown clay and stones
23 - 30 feet	Grey clay
30 - 45 feet	Grey clay and stones
45 - 48 feet	Brown coarse sand and gravel
48 - 50 feet	Grey limestone

TW 16/71

0 - 1 feet	Brown topsoil
1 - 15 feet	Brown clay
15 - 40 feet	Grey clay and stones
40 - 50 feet	Brown coarse sand and gravel

TW 17/71

0 - 1 feet	Brown topsoil
1 - 25 feet	Brown clay and stones
25 - 64 feet	Grey clay and stones
64 - 65 feet	Grey limestone

Municipal Well #1

0 - 1 feet	Topsoil
1 - 10 feet	Brown clay and stones
10 - 17.5 feet	Soft grey clay
17.5 - 25 feet	Gravel
25 - 38 feet	Grey clay
38 - 39 feet	Grey clay
39 - 50 feet	Gravel

Municipal Well #2

0 - 44 feet	Clay and stones
44 - 52 feet	Sand and gravel
52 feet	Limestone

APPENDIX D

CHEMICAL ANALYSES OF WATER SAMPLES

Sample No.	Well Depth (feet)	pH determined by MOE Laboratory	Specific Conductance Micro MHOS/cm @ 25°C	Total Dissolved Solids Content	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	ANIONS: Bicarbonate HCO_3		Chloride Cl		Sulphate SO_4		CATIONS: Calcium Ca		Magnesium Mg		Sodium Na		Potassium K		RATIOS (EPM)				SAR	ION Balance	Error Percent $\frac{\text{Cations-Anions}}{\text{Cations+Anions}} \times 100$
							PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM	$\frac{Ca + Mg}{Na + K}$	$\frac{HCO_3}{SO_4}$	$\frac{HCO_3}{Cl}$	$\frac{SO_4}{Cl}$			
74	(60)	7.8	454	357.7	234.8	194	237	3.9	6	.17	25	0.5	66	3.3	17	1.4	6	0.3	1.2	.03	16.1	7.5	23.0	3.1	0.2	0.4	4.37
60*	(100)	8.3	305	269.8	43.9	152	185	3.0	11	.31	5	0.1	11	0.6	4	0.3	53	2.3	0.5	.01	0.4	29.2	9.8	0.3	3.5	-0.3	-3.84
6	100	8.2	278	237.4	127.4	144	176	2.9	2	.06	9	0.2	23	1.2	17	1.4	10	0.4	0.8	.02	5.6	15.4	51.0	3.3	0.4	-0.1	-1.95
16	117	8.0	309	261.2	152.4	160	195	3.2	1	.03	6	0.1	33	1.7	17	1.4	8	0.4	1.1	.03	8.1	25.6	113.4	4.4	0.3	0.1	1.05
11	120	7.7	420	346.0	209.7	208	254	4.1	2	.08	13	0.3	51	2.6	20	1.6	5	0.2	1.4	.04	16.5	15.4	73.7	4.8	0.2	-0.0	-0.45
18	130	7.9	325	262.1	144.3	156	190	3.1	3	.08	9	0.2	38	1.9	12	1.0	9	0.4	1.0	.02	7.0	16.6	36.8	2.2	0.3	-0.1	-1.37
137	136	7.9	355	279.0	--	--	--	--	4	.11	10	0.2	57	2.8	9	0.7	2	0.1	1.0	.03	31.8	--	--	1.9	0.1	0.2	0.51
133	138	7.9	315	263.7	--	--	--	--	2	.06	10	0.2	57	2.8	6	0.5	2	0.1	0.7	.02	31.8	--	--	3.7	0.1	0.1	0.18
4	153	8.0	325	269.1	169.5	156	190	3.1	1	.03	11	0.2	58	3.0	6	0.5	2	0.1	1.0	.02	30.8	13.6	110.5	8.1	0.1	0.1	1.80
2	(166)	8.0	335	274.4	179.4	158	193	3.2	2	.06	11	0.2	57	2.8	9	0.7	2	0.1	0.8	.02	33.4	13.8	56.0	4.1	0.1	0.3	3.50
55	175	8.3	363	298.2	189.4	166	202	3.3	6	.17	16	0.3	61	3.0	9	0.7	3	0.1	0.8	.02	25.1	10.0	19.6	2.0	0.1	0.1	1.49
48*	188	7.9	438	341.8	126.7	148	181	3.0	15	.42	57	1.2	26	1.3	15	1.2	47	2.0	1.4	.04	1.2	2.5	7.0	2.8	1.8	0.0	0.48
56	(220)	7.8	408	337.7	214.2	196	239	3.9	1	.03	16	0.3	66	3.3	12	1.0	3	0.1	0.7	.02	28.8	11.8	138.9	11.8	0.1	0.1	1.74
127	235	8.0	417	337.8	--	--	--	--	5	.14	21	0.4	68	3.4	10	0.8	4	0.2	0.8	.02	21.7	--	--	3.1	0.1	0.1	1.08
12	(250)	8.2	422	360.8	217.1	210	256	4.1	3	.08	12	0.3	82	4.1	3	0.3	3	0.1	1.8	.05	24.6	16.8	49.6	3.0	0.1	-0.0	0.17
65	(330)	8.0	407	327.7	209.2	188	229	3.8	1	.03	18	0.4	64	3.2	12	1.0	3	0.1	0.5	.01	29.2	10.0	133.2	13.3	0.1	0.2	1.94
58	(10)	8.3	430	364.2	230.8	203	248	4.1	4	.11	24	0.5	71	3.5	13	1.1	4	0.2	0.7	.02	24.0	8.1	36.0	4.9	0.1	0.1	1.43

*water softener suspected

TABLE 20a: Hydrochemistry of ground-water samples collected in the Oak Ridges Moraine area.

Sample No.	Well Depth (feet)	pH determined by MOE Laboratory	Specific Conductance Micro MHOS/cm @ 25°C	Total Dissolved Solids Content	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	ANIONS: Bicarbonate HCO_3 PPM	Bicarbonate HCO_3 EPM	Chloride Cl PPM	Chloride Cl EPM	Sulphate SO_4 PPM	Sulphate SO_4 EPM	CATIONS: Calcium Ca PPM	Calcium Ca EPM	Magnesium Mg PPM	Magnesium Mg EPM	Sodium Na PPM	Sodium Na EPM	Potassium K PPM	Potassium K EPM	RATIOS (epm): $\frac{Ca+Mg}{Na+K}$	$\frac{HCO_3}{SO_4}$	$\frac{HCO_3}{Cl}$	$\frac{SO_4}{Cl}$	SAR	ION Balance	Error Percent $\frac{Cations-Anions}{Cations+Anions} \times 100$
51	65	8.0	331	270.2	149.0	160	195	3.2	6	.17	10	.21	30	1.5	18	1.5	10	.43	1.1	.03	6.4	15.4	18.9	1.2	.36	-0.1	-1.91
22	(70)	7.9	358	303.3	179.0	182	222	3.6	2	.06	13	.27	42	2.1	18	1.5	5	.22	1.4	.04	14.1	13.4	64.5	4.8	.16	-0.1	-1.72
140	(77)	8.0	328	---	---	---	---	---	11	.31	25	.52	94	4.7	9	0.7	5	.22	3.7	.04	17.4	---	---	1.7	.13	---	---
132	78	7.8	357	---	---	---	---	---	17	.48	9	.19	50	2.5	12	1.0	3	.13	0.8	.02	23.1	---	---	0.4	.10	---	---
25	(78)	7.6	575	476.2	308.2	262	320	5.2	7	.20	29	.60	102	5.1	13	1.1	5	.22	0.8	.02	25.9	8.7	26.5	3.1	.12	0.4	2.90
143	80	7.7	630	---	---	---	---	---	19	.54	44	.92	72	3.6	31	2.6	11	.48	3.4	.09	10.9	---	---	1.7	.27	---	---
61	(89)	7.7	493	403.6	247.7	214	261	4.3	14	.39	24	.50	86	4.3	8	0.7	5	.22	6.0	.15	13.6	8.6	10.8	1.3	.14	0.1	1.35
75*	(100)	8.0	444	276.5	70.4	78	95	1.6	92	2.6	5	.10	15	0.8	8	0.7	60	2.6	1.4	.04	0.5	15.0	0.6	0.0	3.1	-0.2	-2.47
5	111	8.1	350	298.6	188.6	172	210	3.4	4	.11	11	.23	64	3.2	7	0.6	2	.09	0.9	.02	34.3	15.0	30.5	2.0	.06	0.1	1.31
130	115	7.9	373	---	---	---	---	---	15	.42	17	.35	42	2.1	19	1.6	16	.70	1.5	.04	5.0	---	---	0.8	.56	---	---
54	115	7.9	442	339.7	214.1	186	227	3.7	10	.28	20	.42	61	3.0	15	1.2	5	.22	1.9	.05	16.1	8.9	13.2	1.5	.15	0.1	1.44
28	(120)	7.6	511	409.7	257.4	215	262	4.3	16	.45	31	.65	80	4.0	14	1.2	5	.22	1.6	.04	20.0	6.7	9.5	1.4	.14	0.0	0.09
7	122	8.2	336	279.0	176.9	160	195	3.2	2	.06	14	.29	56	2.8	9	0.7	2	.09	0.9	.02	32.1	11.0	56.7	5.2	.07	0.1	1.39
66	150	7.9	311	263.1	141.7	160	195	3.2	6	.17	3	.06	32	1.5	15	1.2	11	.48	1.0	.03	5.6	51.2	18.9	0.9	.40	-0.1	-1.39
62	(156)	8.2	459	390.6	234.3	202	246	4.0	17	.48	33	.22	79	3.9	9	0.7	5	.22	1.3	.03	18.7	5.9	8.4	1.4	.14	-0.3	-2.66
19	(165)	7.9	349	306.3	188.2	178	217	3.6	2	.06	17	.35	49	2.5	16	1.3	4	.17	1.3	.03	18.2	10.1	63.1	6.3	.13	0.0	0.02
80	200	7.4	789	600.8	389.6	286	349	5.7	28	.79	53	1.1	128	6.4	17	1.4	20	.87	6.1	.16	7.6	5.9	7.2	1.4	.44	1.2	7.33
53	218	8.0	388	301.7	190.3	154	188	3.1	17	.48	20	.42	63	3.1	8	0.7	5	.22	0.9	.02	15.8	7.4	6.4	0.9	.16	0.1	0.86
52	222	7.9	354	302.3	173.1	178	217	3.6	7	.20	10	.21	38	1.9	19	1.6	10	.11	1.3	.03	7.4	17.1	18.0	1.1	.33	-0.0	-0.44
57	240	7.8	822	682.7	422.2	334	407	6.7	52	1.5	42	.87	146	7.3	14	1.2	19	.83	2.5	.06	9.5	7.6	4.6	0.6	.40	0.3	1.70
141*	259	8.0	328	---	---	---	---	---	5	.14	0	.00	18	0.9	7	0.6	50	2.2	0.8	.02	0.7	0	---	0	2.5	---	---
142	284	7.6	431	---	---	---	---	---	4	.12	18	.37	62	3.1	18	1.5	5	.22	1.3	.03	18.2	---	---	3.3	.14	---	---
15	(10)	7.4	721	573.8	333.3	282	344	5.6	16	.45	54	1.1	117	5.8	10	0.8	20	.87	13.0	.33	5.5	5.0	12.5	2.5	.48	0.7	4.33
24	(10)	7.7	531	425.9	259.4	206	251	4.1	19	.54	45	.94	94	4.7	6	0.5	8	.35	2.7	.07	12.4	4.4	7.7	1.8	.22	0.0	0.11
78	(12)	7.4	930	722.6	474.4	290	354	5.8	37	1.04	125	2.6	157	7.8	20	1.6	19	.83	11.0	.28	8.6	2.2	5.6	2.5	.38	1.2	5.72
115	(20)	7.8	481	401.3	179.7	148	181	3.0	9	.25	114	2.4	39	2.0	20	1.7	37	1.61	1.9	.05	2.2	1.3	11.7	9.4	1.20	-0.3	-3.09

continued

*water softener suspected

TABLE 20 b: Hydrochemistry of ground-water samples collected in the South Slope area above the 700-foot topographic contour.

Sample No.	Well Depth (feet)	pH determined by MOE Laboratory	Specific Conductance Micro MHOS/cm @ 25°C	Total Dissolved Solids Content	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	ANIONS: Bicarbonate HCO_3 PPM	ANIONS: Bicarbonate HCO_3 EPM	ANIONS: Chloride Cl PPM	ANIONS: Chloride Cl EPM	ANIONS: Sulphate SO_4 PPM	ANIONS: Sulphate SO_4 EPM	CATIONS: Calcium Ca PPM	CATIONS: Calcium Ca EPM	CATIONS: Magnesium Mg PPM	CATIONS: Magnesium Mg EPM	CATIONS: Sodium Na PPM	CATIONS: Sodium Na EPM	CATIONS: Potassium K PPM	CATIONS: Potassium K EPM	RATIOS (epm): $\frac{Ca + Mg}{Na + K}$	RATIOS (epm): $\frac{HCO_3}{SO_4}$	RATIOS (epm): $\frac{HCO_3}{Cl}$	RATIOS (epm): $\frac{SO_4}{Cl}$	SAR	ION Balance	Error Percent $\frac{Cations-Anions}{Cations+Anions} \times 100$
79	(20)	8.0	390	304.7	304.7	143	174	2.9	19	.54	34	.71	35	1.8	16	1.3	24	1.0	2.3	.06	2.8	4.0	5.3	1.3	0.8	0.06	0.78
91	24	7.6	505	432.2	273.5	232	283	4.6	6	.17	32	.67	98	4.9	7	0.6	5	0.2	1.3	.03	21.8	7.0	27.4	3.9	0.1	0.25	2.19
46	(25)	7.3	1480	1269.0	512.7	446	544	8.9	106	3.0	260	5.4	174	8.7	19	1.6	157	6.8	10.0	.26	1.5	1.0	3.0	1.8	3.0	0.02	0.04
119	26	7.4	742	558.5	368.3	244	298	4.8	70	2.0	34	.71	131	6.5	10	0.8	6	0.3	10.0	.26	14.2	6.9	2.5	0.4	0.1	0.32	2.06
109	27	7.4	547	454.6	284.1	240	293	4.8	7	0.2	34	.71	94	4.7	12	1.0	6	0.3	9.0	.23	11.6	6.8	24.3	3.6	0.2	0.47	3.94
118	(30)	7.7	416	362.7	226.2	200	244	4.0	4	0.1	24	.50	84	4.2	4	0.3	2	0.1	0.8	.02	42.1	8.0	35.4	4.4	0.1	0.02	0.21
93	(30)	8.2	432	365.0	226.8	200	244	4.0	6	0.2	25	.52	76	3.8	9	0.7	4	0.2	1.1	.03	22.4	7.7	23.6	3.1	0.1	0.05	0.52
9	(30)	7.4	734	586.8	360.5	304	371	6.1	33	0.9	31	.65	118	6.0	16	1.3	16	0.7	2.1	.05	9.6	9.4	6.5	0.7	0.4	0.30	1.94
13	(30)	7.6	616	483.9	308.0	262	320	5.2	19	0.5	21	.44	92	4.6	19	1.5	12	0.5	1.5	.04	11.0	12.0	9.8	0.8	0.3	0.51	3.91
117	30	7.5	536	449.4	268.3	245	299	4.8	5	0.1	27	.56	86	4.2	13	1.1	9	0.4	10.7	.27	8.1	8.7	34.7	4.0	0.2	0.43	3.67
38	(35)	7.9	611	464.4	290.9	239	292	4.8	22	0.6	26	.54	106	5.0	10	0.8	11	0.5	4.0	.10	10.0	8.8	7.7	0.9	0.2	0.46	3.70
42	(39)	7.4	611	478.7	288.3	244	298	4.8	23	0.7	37	.17	94	4.7	13	1.1	13	0.6	1.2	.03	9.7	6.3	7.5	1.2	0.3	0.06	0.49
14	(40)	7.7	390	335.6	206.6	194	237	3.9	1	0.0	20	.42	58	2.9	15	1.2	4	0.2	1.1	.03	20.4	9.3	137.4	14.8	0.1	0.01	0.11
10	(40)	7.3	894	704.5	391.7	348	425	7.0	47	1.3	38	.79	114	5.7	26	2.2	20	0.9	35.0	.89	4.4	9.0	5.2	0.6	0.4	0.52	2.80
Average			541	433.9		228	399		19		38		94								14.2						

TABLE 20b: Continued

Sample No.	Well Depth (feet)	pH determined by MOE Laboratory	Specific Conductance Micro MHOS/cm @ 25°C	Total Dissolved Solids Content	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	ANIONS: Bicarbonate HCO_3 PPM	ANIONS: Bicarbonate HCO_3 EPM	ANIONS: Chloride Cl PPM	ANIONS: Chloride Cl EPM	ANIONS: Sulphate SO_4 PPM	ANIONS: Sulphate SO_4 EPM	CATIONS: Calcium Ca PPM	CATIONS: Calcium Ca EPM	CATIONS: Magnesium Mg PPM	CATIONS: Magnesium Mg EPM	CATIONS: Sodium Na PPM	CATIONS: Sodium Na EPM	CATIONS: Potassium K PPM	CATIONS: Potassium K EPM	RATIOS (epm): $\frac{Ca + Mg}{Na + K}$	RATIOS (epm): $\frac{HCO_3}{SO_4}$	RATIOS (epm): $\frac{HCO_3}{Cl}$	RATIOS (epm): $\frac{SO_4}{Cl}$	SAR	ION Balance	Error Percent $\frac{Cations-Anions}{Cations+Anions} \times 100$
120	9	7.6	508	440.7	273.5	220	268	4.4	28	0.8	30	0.6	98	4.9	7	0.6	8	0.4	1.5	.04	14.2	7.0	5.6	0.8	0.2	0.04	0.36
122	(20)	8.1	337	287.7	168.8	156	190	3.1	4	0.1	21	0.4	61	3.0	4	0.3	3	0.1	4.5	.12	13.7	7.1	27.6	3.9	0.1	-0.05	-0.67
23	(20)	7.4	718	587.2	332.6	302	368	6.0	14	0.4	44	0.9	120	6.0	8	0.7	9	0.4	24.0	.64	6.6	6.6	15.3	2.3	0.2	0.31	2.04
111	(20)	7.3	1090	730.9	524.8	229	279	4.6	151	4.3	72	1.5	192	9.6	11	0.9	25	1.1	0.7	.02	9.5	3.1	1.1	0.4	0.5	1.26	5.73
35	25	7.6	599	459.5	287.7	226	275	4.5	16	0.5	41	0.9	102	5.1	8	0.7	14	0.6	2.9	.07	8.4	5.3	10.0	1.9	0.4	0.61	4.98
121	28	7.5	558	453.3	291.6	232	283	4.6	11	0.3	39	0.8	97	4.8	12	1.0	7	0.3	4.4	.11	14.0	6.7	14.9	2.6	0.2	0.49	4.05
41	(28)	7.7	475	341.1	220.5	158	193	3.2	36	1.0	20	0.4	85	4.2	2	0.2	5	0.2	0.5	.01	19.1	7.6	3.1	0.4	0.1	0.05	0.51
39	29	7.4	683	561.5	289.0	276	336	5.5	28	0.8	42	0.9	91	4.5	15	1.2	18	0.8	31.0	.79	3.7	6.3	7.0	1.1	0.5	0.17	1.18
44	(32)	7.4	644	522.1	305.5	261	318	5.2	25	0.7	47	1.0	91	4.5	19	1.6	14	0.6	7.9	.20	7.5	5.3	7.4	1.4	0.3	0.02	0.12
90	(40)	7.6	750	609.8	345.6	304	371	6.1	27	0.8	49	1.0	112	5.6	16	1.3	33	1.4	2.1	.05	4.6	6.0	8.0	1.3	0.8	0.54	3.31
29	(46)	7.7	422	351.9	219.1	200	244	4.0	2	0.1	24	0.5	63	3.1	15	1.2	3	0.1	1.0	.03	28.1	8.0	70.8	8.9	0.1	-0.02	-0.21
89	57	7.8	1140	646.1	294.8	126	154	2.5	287	8.1	8	0.2	62	3.1	34	2.8	99	4.3	2.5	.06	1.3	15.1	0.3	0.02	2.5	-0.52	-2.46
49	(63)	7.9	730	604.5	357.6	294	358	5.9	15	0.4	66	1.4	130	6.5	8	0.7	13	0.6	14.0	.40	7.7	4.3	13.9	3.3	0.3	0.40	2.52
3	(90)	8.0	345	275.5	177.8	158	193	3.2	3	0.1	11	0.2	58	2.9	8	0.7	2	0.1	0.9	.02	32.3	13.8	37.3	2.7	0.1	0.19	2.68
21	99	7.3	738	613.1	377.6	320	390	6.4	24	0.7	41	0.9	138	6.9	8	0.7	10	0.4	1.9	.05	15.6	7.5	9.5	1.3	0.2	0.10	0.65
40	(100)	7.6	777	574.2	374.8	248	302	5.0	69	2.0	45	0.9	127	6.3	14	1.2	11	0.5	5.8	.15	12.0	5.3	2.6	0.5	0.2	0.28	1.74
1	(100)	7.6	438	338.9	208.8	182	222	3.6	7	0.2	15	0.3	77	3.9	4	0.3	3	0.1	11.0	.28	10.1	11.6	18.4	1.6	0.1	0.44	5.00
87	101	7.7	588	461.6	291.6	234	285	4.7	20	0.6	36	0.7	97	4.8	12	1.0	7	0.3	4.3	.11	14.1	6.2	8.3	1.3	0.2	0.25	2.06
30	129	7.7	728	516.7	309.3	228	278	4.6	32	0.9	56	1.1	109	5.4	9	0.7	91	1.3	1.7	.04	4.4	3.9	5.1	1.3	0.8	0.95	6.67
99	196	7.6	927	720.0	476.6	318	388	6.4	83	2.3	54	1.1	176	8.8	9	0.7	9	0.4	1.3	.03	22.4	5.7	2.7	0.5	0.2	0.13	0.65
73	204	7.4	676	537.7	314.1	254	310	5.1	12	0.3	64	1.3	106	5.3	12	1.0	16	0.7	18.0	.46	5.4	3.8	15.0	3.9	0.4	0.69	4.84

TABLE 20c: Hydrochemistry of ground-water samples collected in the South Slope area below the 700-ft. topographic contour.

							ANIONS						CATIONS								RATIOS (epm)						
Sample No.	Well Depth (feet)	pH determined by MOE Laboratory	Specific Conductance Micro MHOS/cm @ 25°C	Total Dissolved Solids Content	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	Bicarbonate HCO_3		Chloride Cl		Sulphate SO_4		Calcium Ca		Magnesium Mg		Sodium Na		Potassium K		$\frac{Ca + Mg}{Na + K}$	$\frac{HCO_3}{SO_4}$	$\frac{HCO_3}{Cl}$	$\frac{SO_4}{Cl}$	SAR	ION Balance	Error Percent $\frac{Cations-Anions}{Cations+Anions} \times 100$
							PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM	PPM	EPM							
108	7	7.5	444	357	234	194	236	3.9	5	0.1	22	0.5	82	4.1	7	0.6	3	0.1	1.1	0.03	29.4	8.46	27.5	3.25	0.08	0.35	3.77
85	(13)	8.0	357	305	182	168	205	3.4	5	0.1	25	0.5	53	2.6	12	1.0	4	0.2	0.8	0.02	18.7	6.45	23.8	3.69	0.13	-0.19	-2.45
112	14.5	7.5	546	404	275	177	216	3.5	12	0.3	60	1.4	105	5.2	3	0.3	8	0.3	0.6	0.02	15.1	2.83	10.5	3.69	0.21	0.73	6.61
150	26	7.3	709	552	340	285	347	5.7	38	1.1	26	0.5	128	7.0	5	0.4	4	0.2	3.0	0.08	27.1	10.52	5.3	0.51	0.09	-0.26	-1.80
34	(26)	8.0	487	419	255	229	279	4.6	5	0.1	30	0.6	94	4.7	3	0.4	3	0.1	2.0	0.01	26.2	7.33	32.5	4.43	0.08	-0.05	-0.42
102	(27)	7.7	520	436	284	239	291	4.8	3	0.1	27	0.6	104	5.2	6	0.5	2	0.1	2.2	0.01	39.7	9.50	56.4	6.64	0.05	0.40	3.59
101	30	7.5	915	756	482	312	380	6.2	52	1.5	138	2.9	147	7.3	28	2.3	19	0.8	1.5	0.04	11.2	2.17	4.3	1.96	0.38	-0.07	-0.34
113	(30)	7.8	279	234	142	124	151	2.5	4	0.1	18	0.4	55	2.8	1	0.1	2	0.1	3.2	0.08	16.7	6.61	22.0	3.32	0.07	0.03	0.51
114*	(32)	7.3	787	652	376	294	358	5.9	27	0.8	82	1.7	134	6.2	10	0.8	10	0.4	30.0	0.80	6.3	3.44	7.7	2.24	0.23	0.37	2.16
103	35	7.8	581	470	304	239	291	4.8	15	0.4	41	0.9	102	5.1	12	1.0	7	0.3	1.4	0.04	17.9	5.59	11.3	2.02	0.18	0.36	2.93
104	36	7.9	1000	826	487	376	458	7.5	51	1.4	88	1.8	162	8.1	20	1.6	45	2.0	1.4	0.04	4.9	4.10	5.2	1.27	0.89	0.94	4.17
83*	38	7.2	1965	1484	766	556	678	11.1	218	6.2	172	3.6	208	10.3	60	4.9	60	2.6	88.0	2.25	3.2	3.10	1.8	0.58	0.94	-0.66	-1.62
96	(40)	7.3	803	599	404	306	373	6.1	15	0.4	42	0.9	147	7.3	9	1.7	12	0.5	0.5	0.01	15.1	6.99	14.5	2.07	0.26	1.20	7.48
50	(40)	7.6	568	432	280	204	249	4.1	19	0.5	49	1.0	99	4.9	8	0.7	7	0.3	1.1	0.03	16.8	4.00	7.6	1.90	0.18	0.30	2.58
37*	(42)	7.3	933	704	411	327	399	6.5	39	1.1	54	1.1	138	6.9	16	1.3	16	0.7	42.0	1.07	4.6	5.81	5.9	1.02	0.34	1.21	6.48
151	46	7.5	1051	832	529	362	441	7.2	35	1.0	134	2.8	154	7.7	35	2.9	31	1.4	2.0	0.05	7.6	2.59	7.3	2.83	0.59	0.95	4.15
105	48	7.8	939	734	437	310	378	6.2	34	1.0	125	2.7	155	7.7	12	1.0	28	1.2	1.9	0.05	6.9	2.38	6.5	2.71	0.58	0.23	1.18
100	55	7.4	618	409	177	168	205	3.4	89	2.5	6	0.1	33	1.7	23	1.9	50	2.2	2.7	0.07	1.6	26.87	1.3	0.05	1.63	-0.21	-1.78
152	77	7.4	630	508	311	274	334	5.5	16	0.5	33	0.7	95	4.7	18	1.5	11	0.5	1.3	0.03	12.2	7.97	12.1	1.52	0.27	0.12	0.90
153	98	7.8	525	418	257	222	271	4.4	21	0.6	26	0.5	70	3.5	20	1.7	9	0.4	1.6	0.04	11.9	8.19	7.5	0.91	0.24	0.00	0.01
84	119	8.0	669	550	337	284	346	5.8	29	0.8	48	1.0	117	5.8	11	0.9	9	0.4	4.9	0.13	13.1	6.65	9.6	1.44	0.21	0.14	0.97
31*	120	7.4	777	586	363	280	341	5.6	29	0.8	48	1.0	129	6.4	10	0.8	11	0.5	18.0	0.46	7.7	5.60	6.8	1.22	0.25	0.79	5.04
72	168	7.8	318	272	135	152	185	3.4	15	0.4	10	0.2	26	1.3	17	1.4	17	0.7	1.7	0.04	3.4	14.59	7.2	0.49	0.64	-0.19	-2.65
Average (total)		7.6	714	563	338	264	322		34		56		110		15		16		9.3		13.8	6.99	12.8	2.16	0.37		

*possible outside pollution - high K values

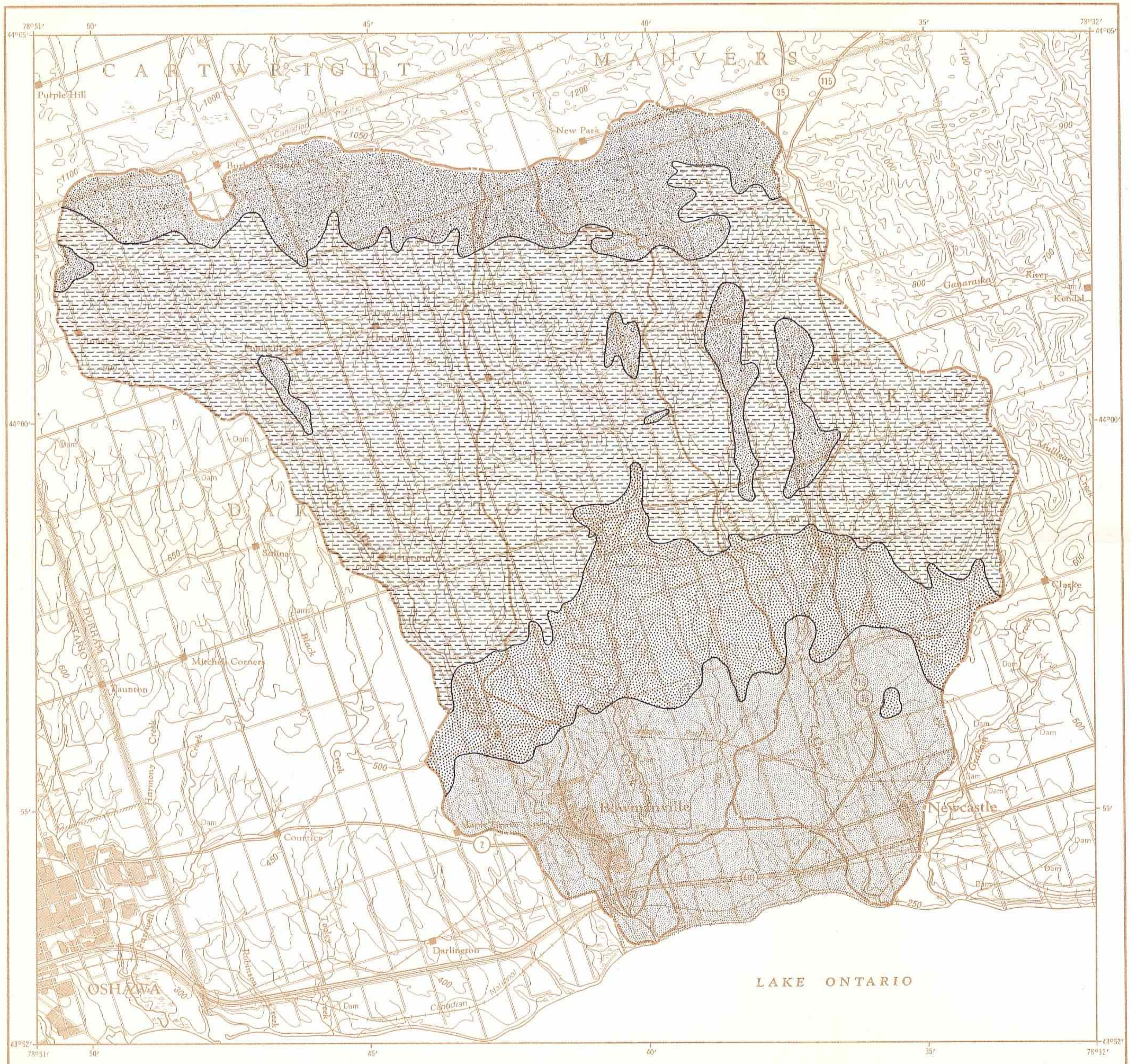
TABLE 20d: Hydrochemistry of ground-water samples collected in the Lake Plain area.

Sample No.	Well Depth (feet)	pH determined by MOE Laboratory	Specific Conductance Micro MHOS/cm @ 25°C	Total Dissolved Solids Content	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	ANIONS: Bicarbonate HCO_3 PPM	Bicarbonate HCO_3 EPM	Chloride Cl PPM	Chloride Cl EPM	Sulphate SO_4 PPM	Sulphate SO_4 EPM	CATIONS: Calcium Ca PPM	Calcium Ca EPM	Magnesium Mg PPM	Magnesium Mg EPM	Sodium Na PPM	Sodium Na EPM	Potassium K PPM	Potassium K EPM	RATIOS (epm): $\frac{Ca + Mg}{Na + K}$	$\frac{HCO_3}{SO_4}$	$\frac{HCO_3}{Cl}$	$\frac{SO_4}{Cl}$	SAR	ION Balance	Error Percent $\frac{Cations-Anions}{Cations+Anions} \times 100$
125		7.7	373	296	187	205	250	3.4	3	.09	16	.33	60	3.0	9	0.7	2	.09	1.3	.03	31.1	10.1	39.7	3.9	0.06	0.08	1.01
126		7.9	340	288	188	201	245	3.3	3	.09	15	.31	52	2.6	14	1.2	2	.09	0.9	.02	34.1	10.5	38.9	3.7	0.06	0.17	2.19
128		8.1	460	401	254	288	351	4.7	4	.11	11	.23	82	4.1	12	1.0	3	.13	0.9	.02	33.1	20.6	41.8	2.0	0.08	0.17	1.66
129		8.2	406	354	227	249	304	4.1	3	.09	16	.33	68	3.4	14	1.2	3	.13	0.9	.02	29.6	12.3	48.2	3.9	0.08	0.20	2.17
131		7.8	284	240	151	138	168	2.7	2	.06	9	.19	54	2.7	4	0.3	2	.09	0.7	.01	28.8	14.7	48.9	3.3	0.07	0.13	2.08
134		7.9	357	302	191	216	263	3.5	1	.03	10	.21	65	3.2	7	0.6	2	.09	0.6	.01	37.3	17.0	125.5	7.4	0.06	0.15	1.89
136		7.7	492	397	246	283	345	4.6	5	.14	16	.33	72	3.6	16	1.3	4	.17	0.9	.02	24.9	13.9	32.9	2.4	0.11	-0.01	-0.06
138		7.8	431	338	207	241	294	4.0	3	.09	9	.10	78	3.9	3	0.3	3	.13	1.1	.03	26.1	21.1	46.7	2.2	0.09	0.08	0.89
144		7.9	431	352	218	245	299	4.0	4	.11	18	.37	71	3.5	10	0.8	3	.13	1.1	.03	27.5	10.7	35.6	3.3	0.08	0.02	0.24
145		7.8	504	420	258	296	361	4.9	5	.14	19	.40	82	4.1	13	1.1	4	.17	1.3	.03	24.9	12.3	34.4	2.8	0.11	-0.02	-0.18
148		7.7	489	396	253	269	328	4.4	4	.11	25	.52	80	4.0	13	1.1	4	.17	1.1	.03	25.4	8.5	39.1	4.6	0.11	0.22	2.15
St. Mary's Quarry (bedrock)																											
SM1		6.9	2576	1682	861	434	529	8.7	611	17.2	87	1.8	203	10.1	86	7.1	158	6.9	7.6	0.2	2.43	4.8	0.50	0.11	2.34	-3.45	-6.63
SM2		6.9	9999+	7573	3702	297	362	5.9	4490	--	31	0.6	1080	53.9	244	20.1	1330	7.9	36.0	0.9	1.26	9.2	0.05	0.01	9.51	-0.49	-0.18

TABLE 20e: Hydrochemistry of seepage samples

Sample No.	Well Depth (feet)	pH determined by MOE Laboratory	Specific Conductance Micro MHOS/cm @ 25°C	Total Dissolved Solids Content	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	ANIONS: Bicarbonate HCO_3 PPM	Bicarbonate HCO_3 EPM	Chloride Cl PPM	Chloride Cl EPM	Sulphate SO_4 PPM	Sulphate SO_4 EPM	CATIONS: Calcium Ca PPM	Calcium Ca EPM	Magnesium Mg PPM	Magnesium Mg EPM	Sodium Na PPM	Sodium Na EPM	Potassium K PPM	Potassium K EPM	RATIOS (epm): $\frac{Ca + Mg}{Na + K}$	$\frac{HCO_3}{SO_4}$	$\frac{HCO_3}{Cl}$	$\frac{SO_4}{Cl}$	SAR	ION Balance	Error Percent $\frac{Cations-Anions}{Cations+Anions} \times 100$
STREAM SAMPLES FROM TILL PLAIN AREA																											
26	NA	8.4	372	312	194	176	215	3.5	3	.09	20	0.4	63	3.1	9	0.7	2	.09	0.9	.02	35.3	8.4	41.6	4.9	.06	- .02	- 0.30
27	"	8.2	375	307	196	172	210	3.4	2	.06	20	0.4	62	3.1	10	0.8	3	.13	0.9	.02	25.5	8.3	60.9	7.4	.09	.16	2.01
32	"	8.3	417	370	226	212	256	4.2	3	.09	18	0.4	84	4.2	4	0.3	2	.09	0.6	.01	44.2	11.3	50.1	4.4	.06	- .07	- 0.78
33	"	8.0	424	382	334	220	268	4.4	3	.09	18	0.4	82	4.1	7	0.6	3	.13	1.2	.03	29.0	11.7	52.0	4.4	.08	- .03	- 0.27
36	"	8.3	445	375	230	211	257	4.2	4	.11	23	0.5	79	3.9	8	0.6	3	.13	1.0	.03	29.5	8.8	37.4	4.2	.09	- .05	- 0.54
45	"	7.8	413	367	219	212	259	4.2	3	.09	18	0.4	73	3.6	9	0.7	5	.22	1.0	.03	18.0	11.3	50.1	4.4	.15	- .07	- 0.74
59	"	7.2	721	608	377	305	372	6.1	48	1.3	31	0.6	136	6.8	9	0.7	9	.39	3.1	.08	16.0	9.4	4.5	0.5	.20	- .10	- 0.60
67	"	7.5	676	529	357	268	327	5.4	17	.48	48	1.0	110	5.5	20	1.6	7	.30	1.1	.03	21.4	5.4	11.2	2.1	.16	.63	4.43
88	"	7.4	672	528	324	260	317	5.2	23	.65	42	0.9	115	5.7	9	0.7	7	.30	15	.38	9.4	6.0	8.0	1.4	.17	.45	3.23
106	"	7.9	346	290	183	165	201	3.3	3	.09	15	0.3	60	3.0	8	0.6	2	.09	0.7	.02	34.8	10.6	39.0	3.7	.06	.06	0.85
107	"	8.4	1109	302	187	170	207	3.4	3	.99	20	0.4	60	3.0	9	0.7	2	.09	0.8	.02	34.7	8.2	40.1	4.9	.06	- .06	- 0.73
STREAM SAMPLES FROM LAKE PLAIN AREA																											
82	"	8.0	446	367	232	190	232	3.8	4	0.1	36	0.7	88	4.4	3	0.3	3	0.1	1.0	.04	27.1	5.1	33.6	6.6	0.09	0.15	1.59
97	"	8.3	381	315	201	171	209	3.4	7	0.2	21	0.4	64	3.2	10	0.8	4	0.2	0.9	.02	20.4	7.8	17.3	2.2	0.12	0.16	1.96
98	"	8.3	443	380	241	199	243	4.0	8	0.2	27	0.6	80	4.0	10	0.8	11	0.5	1.5	.04	9.3	7.1	17.6	2.5	0.31	0.57	5.62

TABLE 20f. Hydrochemistry of surface - water samples
* NA - Not Applicable



LEGEND

Oakridges Interlobate Kame Moraine: upland

South Slope: till plain

Lake Iroquois Plain: upper lake plain

Lake Iroquois Plain: lower lake plain

SOURCES OF INFORMATION

Physiographic subdivisions modified by G. Funk, 1974, from Chapman, L.J., and Putnam, D.F., 1966; The physiography of southern Ontario; University of Toronto Press.

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Ontario

MINISTRY OF THE ENVIRONMENT
Water Resources Branch

INTERNATIONAL HYDROLOGICAL DECADE

BOWMANVILLE, SOPER AND WILMOT CREEKS DRAINAGE BASIN

MAP 1

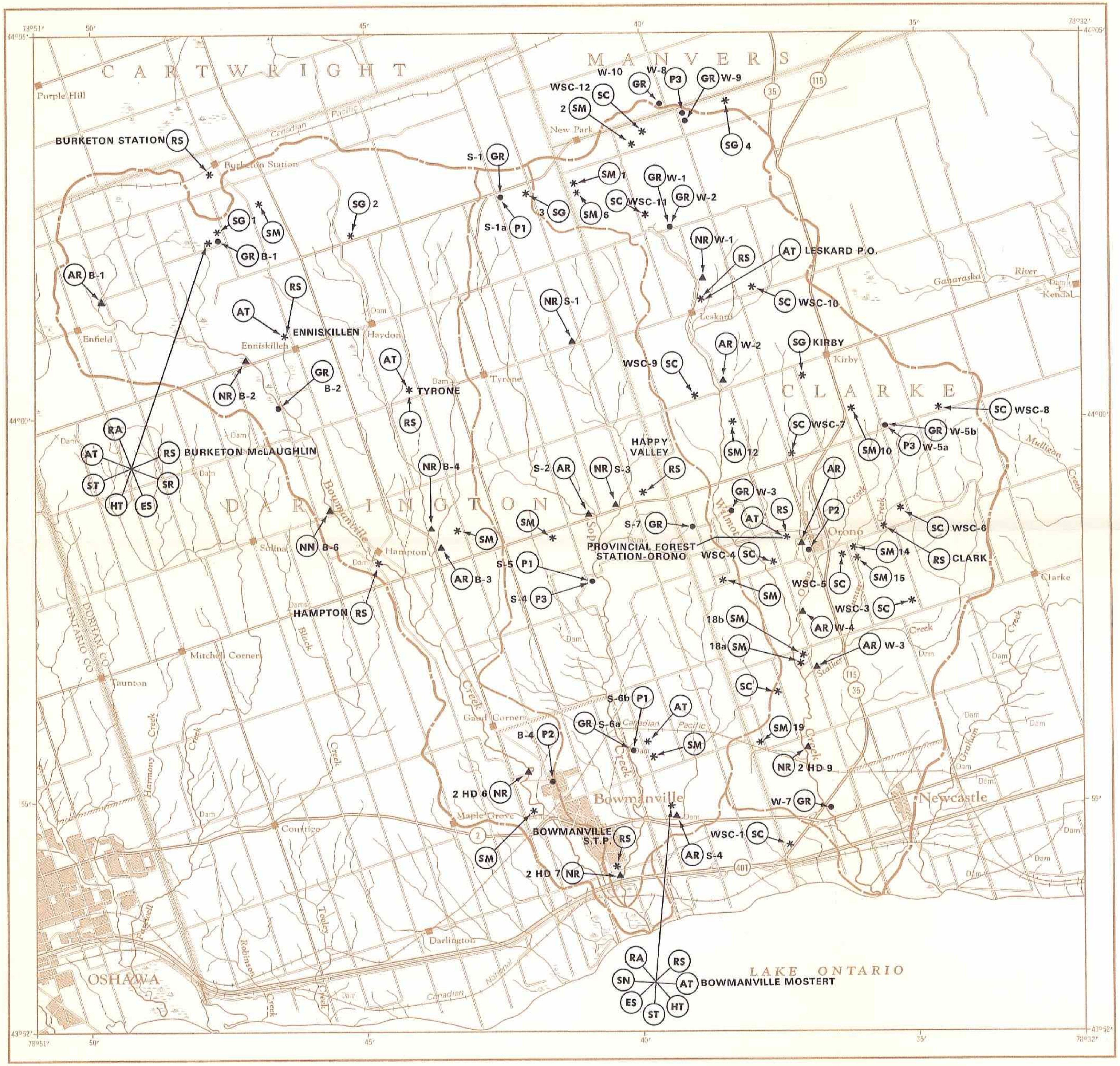
PHYSIOGRAPHIC SUBDIVISIONS

Scale 1:100,000
1 inch equals 1.58 miles

1 0 1 2 3 Miles

1 0 1 2 3 4 5 Kilometres

MAP 2107



LEGEND

NR	Hydrometric station, natural control, recording
NN	Hydrometric station, natural control, non-recording
AR	Hydrometric station, artificial control, recording
GR	Groundwater well, recording
P*	Piezometer (asterisk replaced by number of piezometers in nest)
SC	Snow course
SG	Snow gauge
RA	Rain gauge, recording
RS	Rain gauge, standard
HT	Hygrothermograph
SN	Radiometer
SR	Sunshine recorder
ES	Evaporation station
SM	Soil moisture site
ST	Soil temperature site
AT	Air temperature site

SYMBOLS

▲	Streamflow station
●	Groundwater well
*	Meteorological station

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BOWMANVILLE, SOPER AND WILMOT CREEKS DRAINAGE BASIN

MAP 2

BASIN INSTRUMENTATION

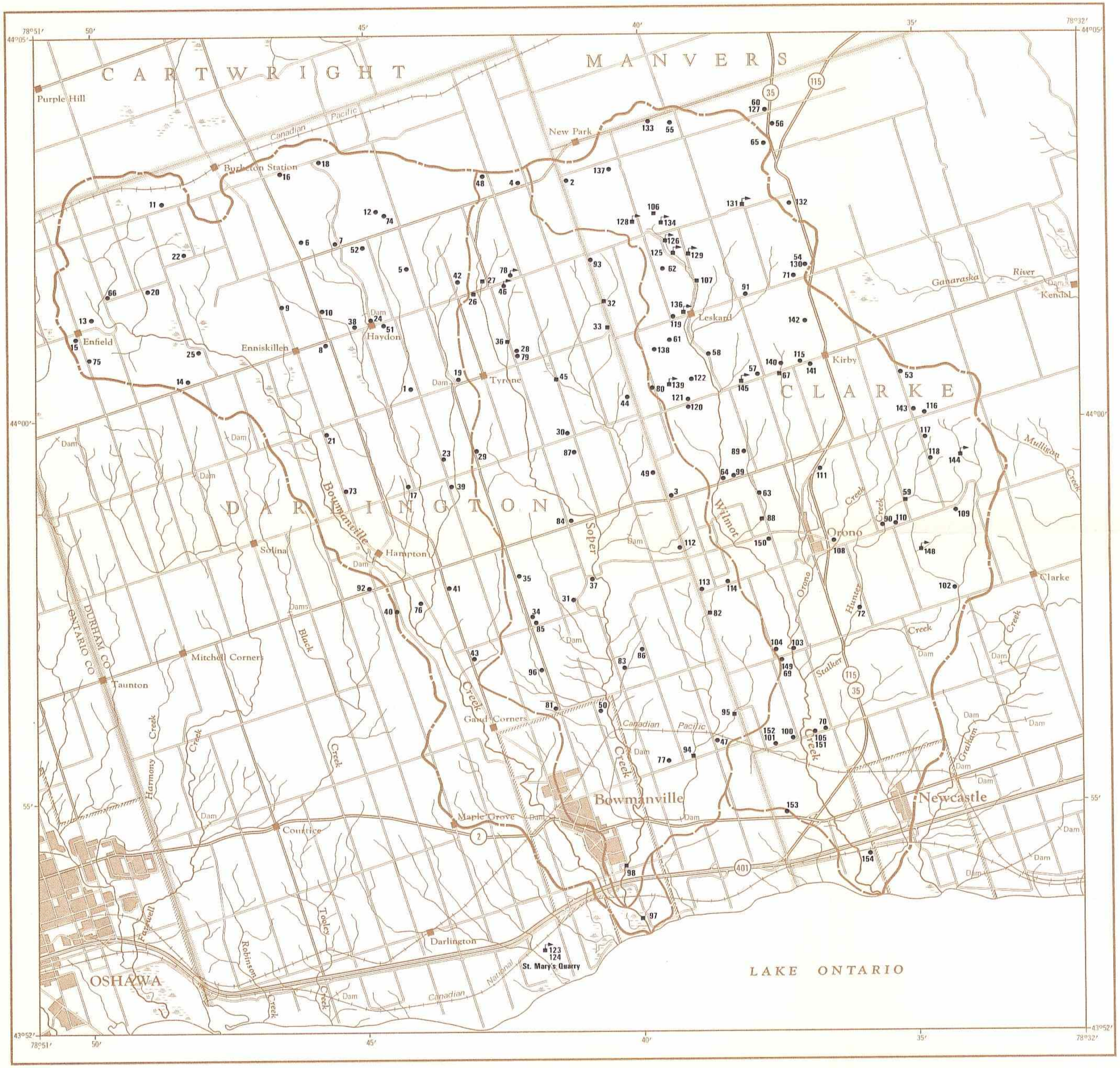
Scale 1:100,000
1 inch equals 1.58 miles

1 0 1 2 3 Miles

1 0 1 2 3 4 5 Kilometres

MAP 2108

BOWMANVILLE, SOPER AND WILMOT CREEKS—MAP 7
WATER SAMPLE LOCATIONS



LEGEND

	Flowing well sample
	Stream sample
	Seepage sample
	Water well sample
87	Sample number

SOURCES OF INFORMATION

Samples were collected in 1968 and 1971 by M. Barouch.

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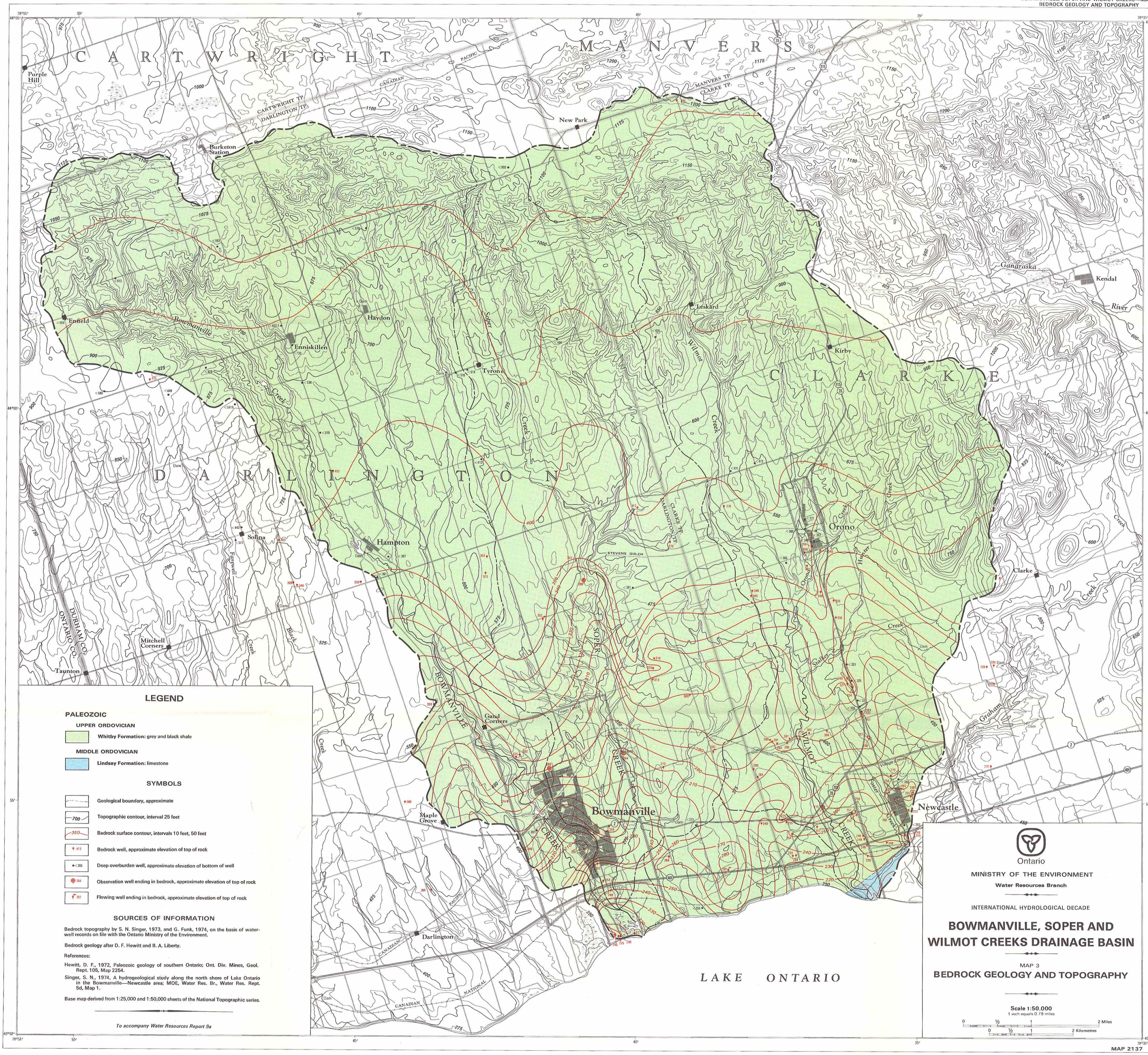
BOWMANVILLE, SOPER AND WILMOT CREEKS DRAINAGE BASIN

MAP 7

WATER SAMPLE LOCATIONS

Scale 1:100,000
1 inch equals 1.58 miles

MAP 2179



LEGEND

PALEOZOIC

UPPER ORDOVICIAN

Whitby Formation: grey and black shale

MIDDLE ORDOVICIAN

Lindsay Formation: limestone

SYMBOLS

- Geological boundary, approximate
- 700 — Topographic contour, interval 25 feet
- 350 — Bedrock surface contour, intervals 10 feet, 50 feet
- 412 — Bedrock well, approximate elevation of top of rock
- <365 — Deep overburden well, approximate elevation of bottom of well
- 264 — Observation well ending in bedrock, approximate elevation of top of rock
- 297 — Flowing well ending in bedrock, approximate elevation of top of rock

SOURCES OF INFORMATION

Bedrock topography by S. N. Singer, 1973, and G. Funk, 1974, on the basis of water-well records on file with the Ontario Ministry of the Environment.

Bedrock geology after D. F. Hewitt and B. A. Liberty.

References:

Hewitt, D. F., 1972, Paleozoic geology of southern Ontario; Ont. Div. Mines, Geol. Rept. 105, Map 2254.

Singer, S. N., 1974, A hydrogeological study along the north shore of Lake Ontario in the Bowmanville—Newcastle area; MOE, Water Res. Br., Water Res. Rept. 5d, Map 1.

Base map derived from 1:25,000 and 1:50,000 sheets of the National Topographic series.

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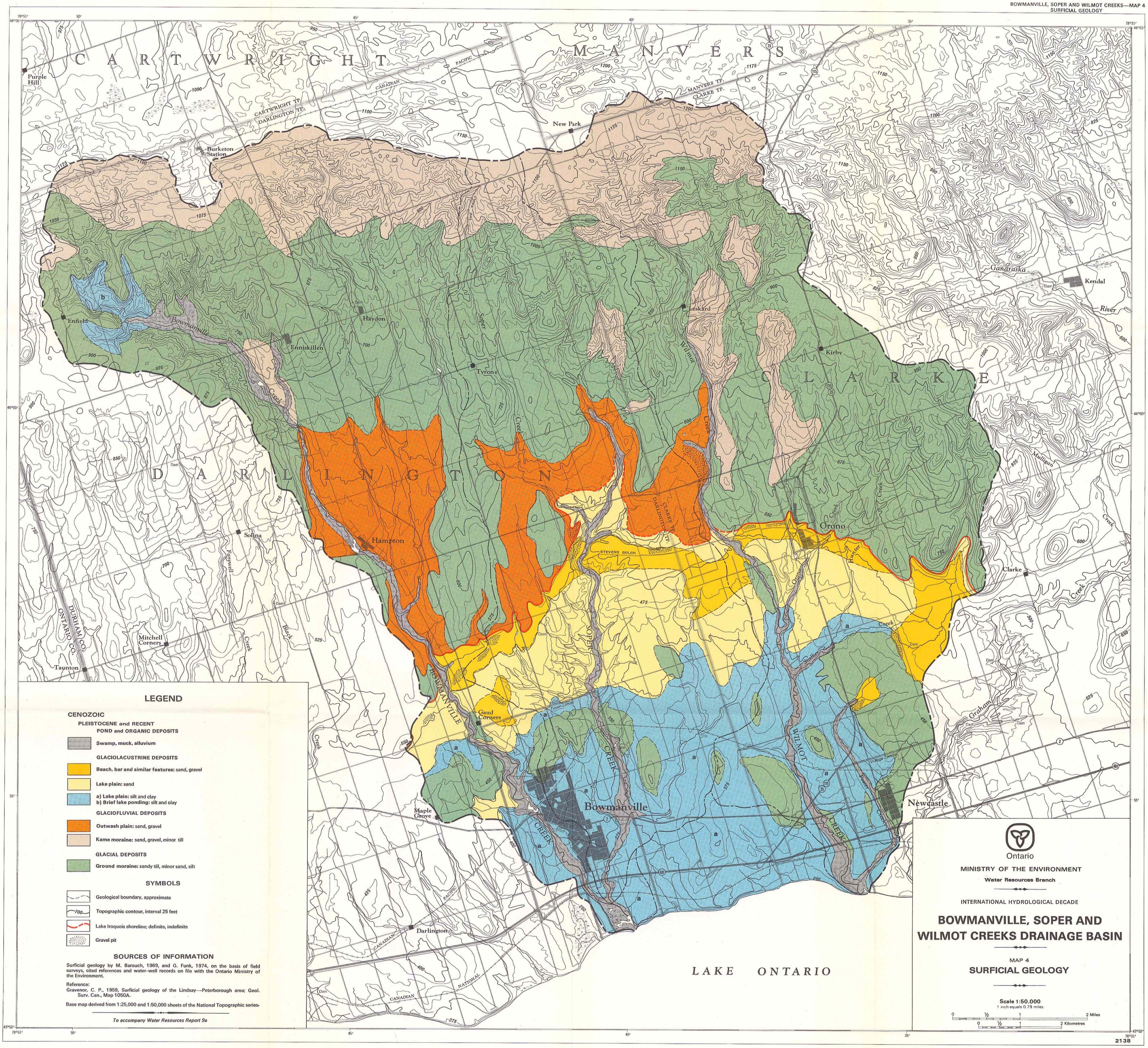
BOWMANVILLE, SOPER AND WILMOT CREEKS DRAINAGE BASIN

MAP 3

BEDROCK GEOLOGY AND TOPOGRAPHY

Scale 1:50,000
1 inch equals 0.79 miles

0 ½ 1 2 Miles
0 ½ 1 2 Kilometres


CARTWRIGHT
MANVERS
DARLINGTON
CLARKE
CARTWRIGHT TP.
DARLINGTON TP.
MANVERS TP.
CLARKE TP.
DURHAM CO.
ONTARIO CO.
Purple Hill
Burketon Station
New Park
Enfield
Haydon
Enniskillen
Tyrone
Leskard
Kirby
Kendal
Hampton
Solina
Mitchell Corners
Taunton
Orono
Clarke
Gaud Corners
Maple Grove
Bowmanville
Newcastle
Darlington
STEVENS GULCH
Bowmanville Creek
Soper Creek
Wilmot Creek
Ganaraska River
Mulligan Creek
Graham Creek
Black Creek
Farewell Creek
LAKE ONTARIO
LEGEND
CENOZOIC
PLEISTOCENE and RECENT
POND and ORGANIC DEPOSITS
Swamp, muck, alluvium
GLACIOLACUSTRINE DEPOSITS
Beach, bar and similar features: sand, gravel
Lake plain: sand
a) Lake plain: silt and clay
b) Brief lake ponding: silt and clay
GLACIOFLUVIAL DEPOSITS
Outwash plain: sand, gravel
Kame moraine: sand, gravel, minor till
GLACIAL DEPOSITS
Ground moraine: sandy till, minor sand, silt
SYMBOLS
Geological boundary, approximate
Topographic contour, interval 25 feet
Lake Iroquois shoreline; definite, indefinite
Gravel pit
SOURCES OF INFORMATION
Surficial geology by M. Barouch, 1969, and G. Funk, 1974, on the basis of field surveys, cited references and water-well records on file with the Ontario Ministry of the Environment.
Reference:
Gravenor, C. P., 1959, Surficial geology of the Lindsay—Peterborough area; Geol. Surv. Can., Map 1050A.
Base map derived from 1:25,000 and 1:50,000 sheets of the National Topographic series.
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BOWMANVILLE, SOPER AND WILMOT CREEKS DRAINAGE BASIN
MAP 4
SURFICIAL GEOLOGY
Scale 1:50,000
1 inch equals 0.79 miles
2 Miles
2 Kilometres
78°51′
43°52′
78°31′
2138

LEGEND

- Water well
- Flowing well
- Observation well
- 969 Well number
- A_1 A_2 Line of cross-section

SOURCES OF INFORMATION

Locations of water wells compiled by S. N. Singer, 1973, and G. Funk, 1974, on the basis of water-well records on file with the Ontario Ministry of the Environment.

Reference:

Singer, S. N., 1974, A hydrogeological study along the north shore of Lake Ontario in the Bowmanville—Newcastle area; MOE, Water Res. Br., Water Res. Rept. 5d, Map 3.

Base map derived from 1:25,000 and 1:50,000 sheets of the National Topographic series.

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BOWMANVILLE, SOPER AND WILMOT CREEKS DRAINAGE BASIN

MAP 5

LOCATIONS OF SELECTED WATER WELLS AND CROSS SECTIONS

Scale 1:50,000
1 inch equals 0.79 miles

0 ½ 1 2 Miles
0 ½ 1 2 Kilometres

2139

LEGEND

750	Water-level contour, interval 50 feet
•	Water well ending in overburden
	Water well ending in bedrock
	Flowing well ending in overburden
	Flowing well ending in bedrock
572	Water level

SOURCES OF INFORMATION

Water-level contours by S. N. Singer, 1973, and G. Funk, 1974, on the basis of water-well records on file with the Ontario Ministry of the Environment.

Reference:

Singer, S. N., 1974, A hydrogeological study along the north shore of Lake Ontario in the Bowmanville—Newcastle area; MOE, Water Res. Br., Water Res. Rept. 5d, Map 4.

Base map derived from 1:25,000 and 1:50,000 sheets of the National Topographic series.

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BOWMANVILLE, SOPER AND WILMOT CREEKS DRAINAGE BASIN

MAP 6

WATER LEVEL CONTOURS IN THE OVERBURDEN

Scale 1:50,000
1 inch equals 0.79 miles

0 ½ 1 2 Miles
0 ½ 1 2 Kilometres

MAP 2140

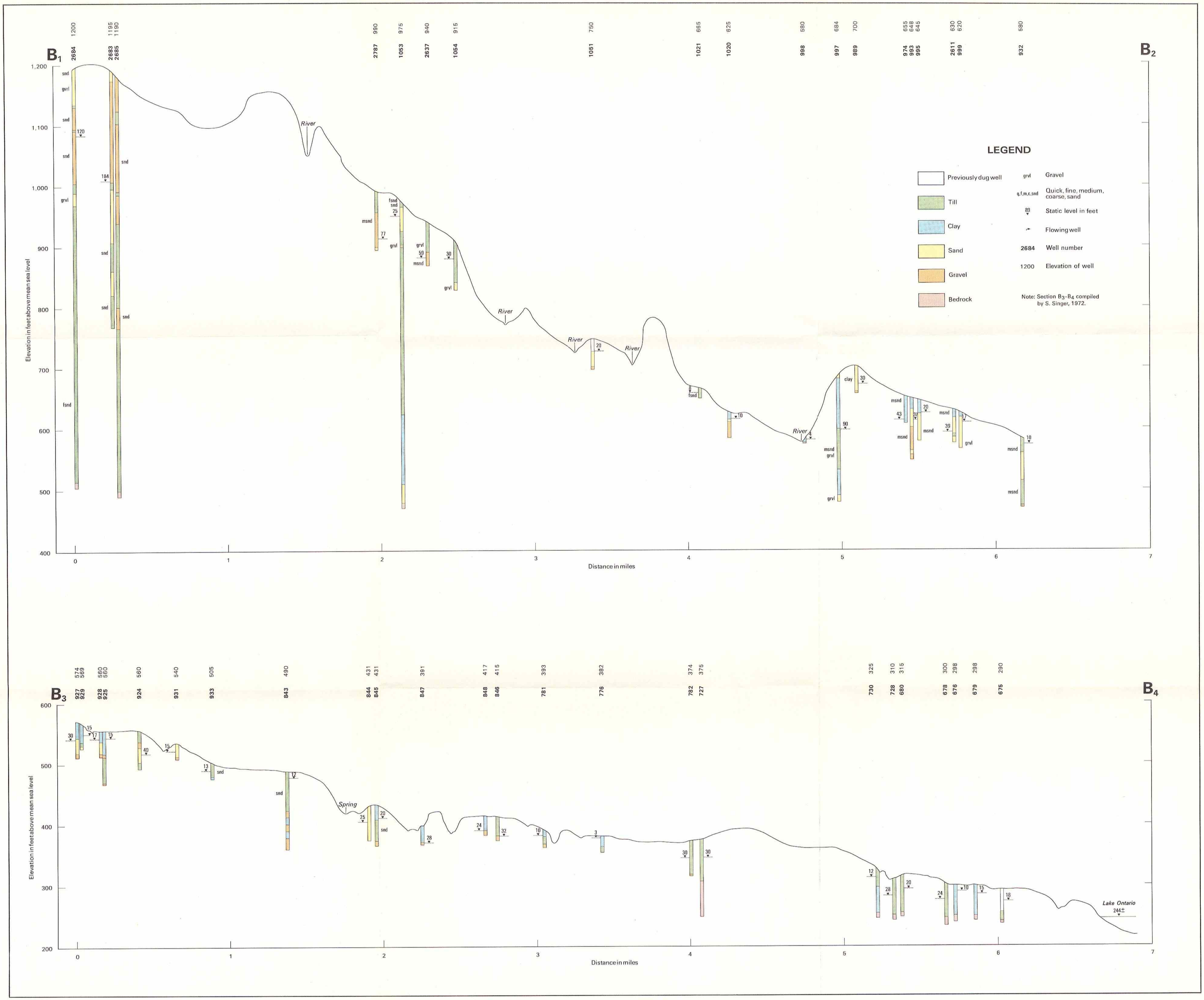
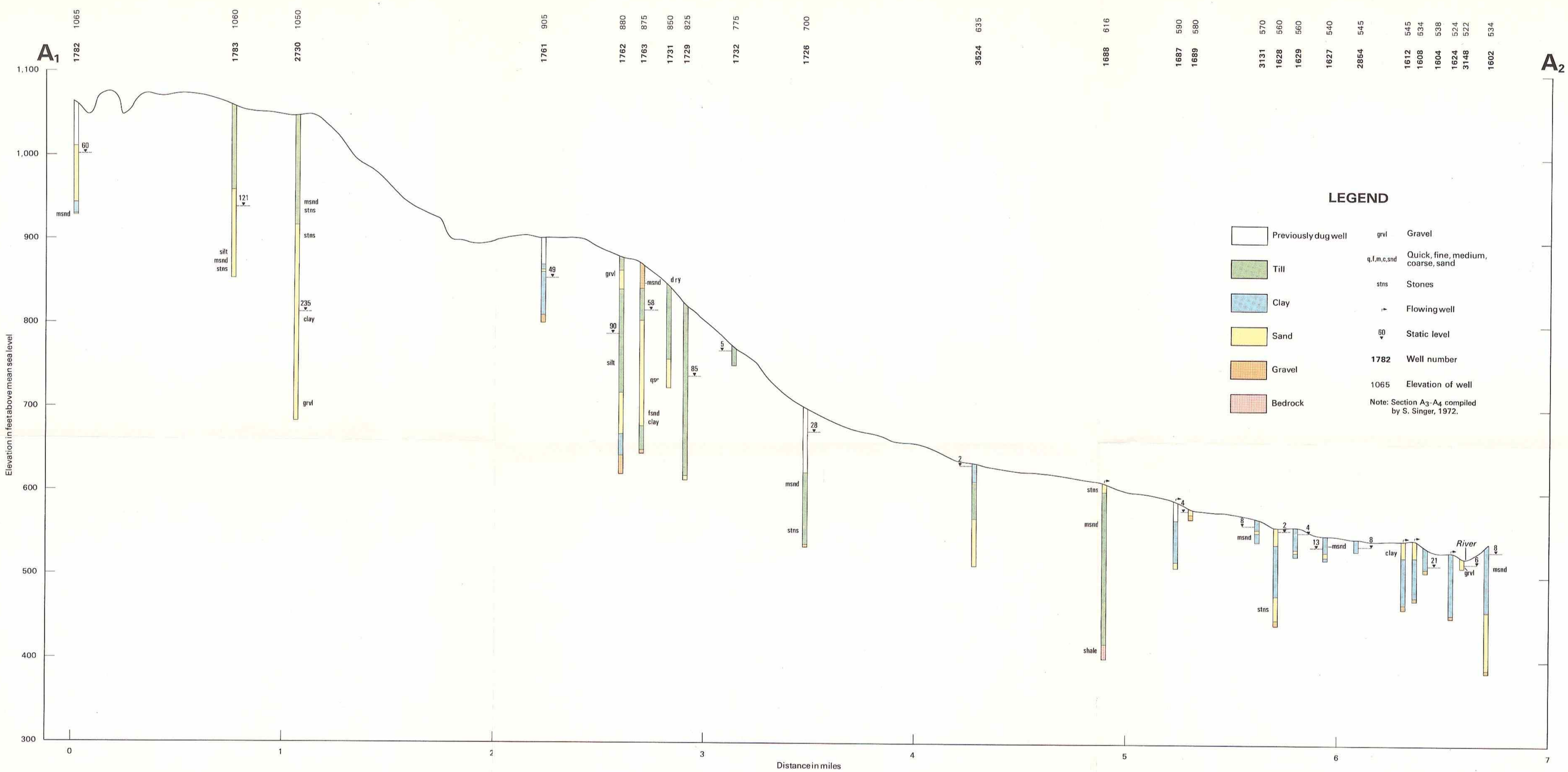


Figure 3. North-south cross-section through the eastern part of the basin.


A1
A2
Elevation in feet above mean sea level
Distance in miles
LEGEND
Previously dug well
Till
Clay
Sand
Gravel
Bedrock
grvl Gravel
q,f,m,c,snd Quick, fine, medium, coarse, sand
stns Stones
Flowing well
60 Static level
1782 Well number
1065 Elevation of well
Note: Section A3-A4 compiled by S. Singer, 1972.
River

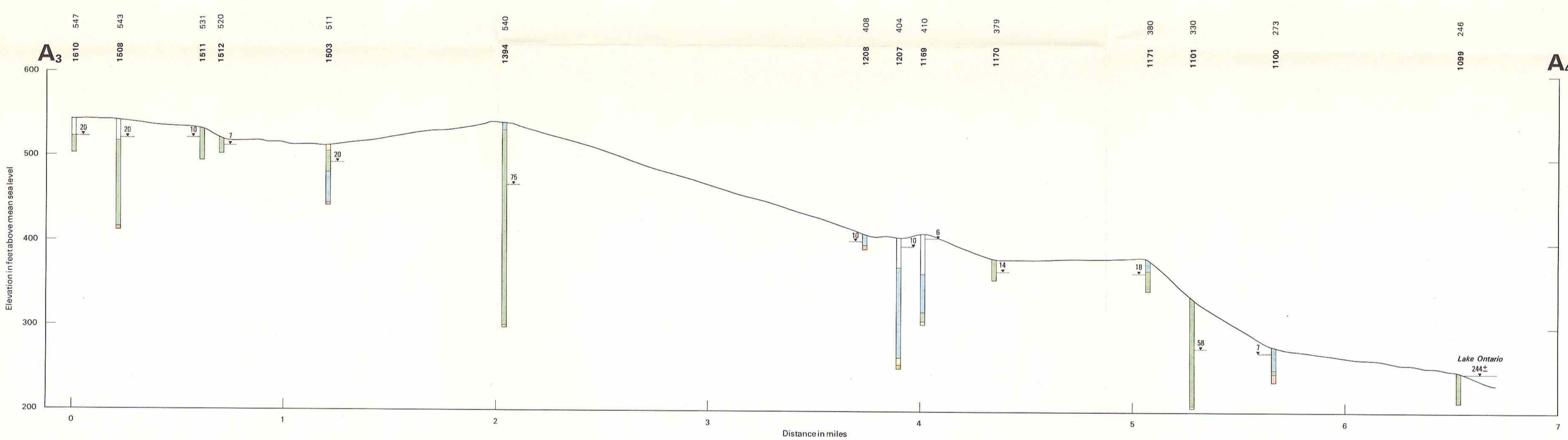

A3
A4
Elevation in feet above mean sea level
Distance in miles
Lake Ontario
244±

Figure 5. East-west cross-section through the South Slope physiographic region.